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Radio Telegraphy

BY GUGLIELMO MARCONI

Honorary Member A. I. E. E.

The lecture first deals briefly with the early history of long distance radio communication.

The work carried out by the engineers and experts of the Marconi Company in England with electron tubes or triode valves shows that, according to their experience, greater efficiency can be obtained at present by a number of bulbs used in parallel than by the employment of large single unit tubes.

Information is given in a general way in regard to recent practise in the design and construction of receivers with the object especially of improving selectivity, reducing interference, and concerning the possible speed of working.

The lecture also deals briefly with results obtained at receiving observation stations situated in various far distant parts of the world, where it has been ascertained that radio signals arriving from high-power stations situated at or near the antipodes of the observation stations, reach the receivers by various ways around the earth, not always following the shortest great circle route, and also that at such places the electric waves coming around by different ways do in certain cases increase this effect on the receivers whilst in others interfere with each other.

It has also been noticed that apparently transmission is easier from west to east than from east to west, and that it may be necessary to modify somewhat the transmission formula for long distances.

It has also been ascertained that the most troublesome atmospheric disturbances or static usually come from the continents and not from the oceans.

The lecture further deals with a study of short electrical waves and the results which have been obtained with such waves of a length from 1 meter to 20 meters, and describes tests whi h show for the first time that electric waves of under 20 meters in length, used in connection with suitable reflectors, are quite capable of providing a good and reliable point-to-point, unidirectional system of radio over quite considerable distances.

The application of this system as a direction finder in aid of navigation, and as a method for preventing collisions at sea, is also dealt with.

THE first occasion on which I had the honor of speaking before the members of the American Institute of Electrical Engineers was of a very festive nature.

It is over twenty years ago, to be exact on January 13, 1902; (there was not then any Radio Institute in existence) and on that date, memorable for me, I was entertained by over 300 members of your Institute at a dinner at the Waldorf-Astoria in this City. I was offered that dinner following my announcement of the fact that I had succeeded in getting the first radio signal across the Atlantic Ocean.

Many men, whose names are household words in electrical science, were present, men such as Dr. Alexander Graham Bell, Professor Elihu Thompson, Dr. Steinmetz, Dr. Pupin, Mr. Frank Sprague, and many others.

The function was one I shall never forget, and displayed to the full American resource and originality, as only forty-eight hours' notice of the dinner had been given, but what has left the greatest impression on my mind during all the long twenty years that have passed is the fact that you believed in me and in what I told you about having got the simple letter "S" for the first time across the ocean from England to Newfoundland without the aid of cables or conductors.

It gives me now the greatest possible satisfaction to say that in some measure, perhaps, your confidence in my statement was not misplaced, for those first feeble signals which I received at St. John's Newfoundland, on the 12th of December, 1901, had proved once and for all that electric waves could be transmitted and received across the ocean, and that long distance radiotelegraphy, about which so many doubts were then entertained, was really going to become an established fact.

You will easily understand my feelings and how very happy I am to have the honor of addressing you again tonight, and when I say that I will always treasure the recollection of the generous encouragement and valid support so heartily extended to me practically at the commencement of my career, when perhaps I most needed it, by such a distinguished and authoritative body as the American Institute of Electrical Engineers.

The subject of my lecture, "Radiotelegraphy," has become so vast and so complex that you will readily understand my difficulty as to where I shall begin and as to when I ought to stop. It would be quite impossible for me to descant at any length on present achievements in a country which in a very short time has made gigantic strides in the scientific development and practical application of the science and art of radiotelegraphy. Moreover, time will not allow me to do more than skin over only a very few of the many problems which have lately been solved, or which there is a good prospect of solving in the near future.

Although we have, or believe we have, all the necessary data for the generation, transmission and reception of electrical waves, as at present utilized for radiotelegraphy, we are still far from possessing exact knowledge concerning the conditions governing the transmission, or rather the propagation, of these waves through space, especially over long distances.

I propose tonight to bring to your notice some of the recent results attained in Europe and elsewhere and to call your attention particularly to what I consider a somewhat neglected branch of the art; and which is the study of the characteristics and properties of

Presented at a joint meeting of the New York Section of the A. I. E. E. and The Institute of Radio Engineers, New York, June 20, 1922.

very short electrical waves. My belief is always that, only by the careful study and analysis of the greatest possible number of well authenticated facts and results, will it be possible to overcome the difficulties that still lie in the way of the practical application of radio in the broadest possible sense.

A very great impulse has been given to radiotelegraphy and telephony by the discovery and utilization of the oscillating electron tube or triode valve based on the observations and discoveries of Edison and Fleming, of those of DeForest and of those of Meissner in Germany, Langmuir and Armstrong in America, and H. W. Round in England, who have also brought it to a practical form as a most reliable generator of continuous electric waves.

As the electron tube, or triode value, or value ar it is now generally called in England, is able, not only to act as a detector, but also to generate oscillations, it has supplied us with an arrangement which is fundamentally similar for both transmitter and receiver, providing us also by a simple and practical method with the means for obtaining beat reception and on almost unlimited magnification of the strength of signals.

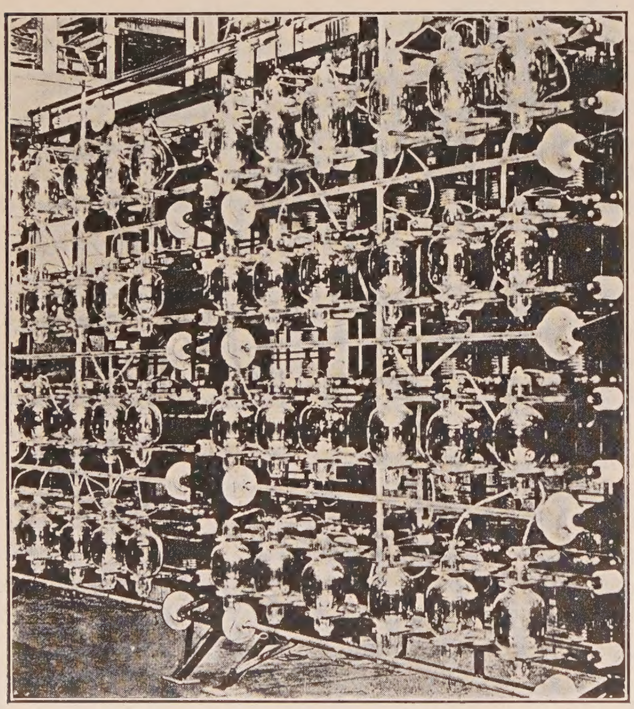

Fig. 1—Tube Panel at Carnarvon

A result of the introduction of the triode value has been that the basic inventions which made long distanee radiotelegraphy possible have become more and more valuable.

It may perhaps be of interest if I give some information as to the progress made by the Marconi Company in England, with the practical application of the triode valve.

It has been so far our practise to use a plurality of tubes in parallel at our long distance stations. High power has been obtained in practise up to 100 kilowatts in the antenna by means of a number of glass tubes in parallel, and for the present we are standardizing units capable of supplying 4 kilowatts to the antenna, in the numbers required and sufficient for each particular case.

Some difficulty was at first experienced in paralleling large tubes in considerable numbers, but no difficulties now occur with groups of sixty bulbs working on voltages of 12,000 on the plate.

I am told that no insurmountable difficulty would be encountered if it were desired to supply 500 kilowatts to the antenna from a number of these bulbs. The life of the bulbs has been very materially increased and the 4-kw. units are expected to have a life which, based on a great number of tests carried out both in the laboratory and at our Clifden station, should be well in excess of 5000 hours.

The development of single-unit tubes of considerable power is also progressing. We have lately concentrated on the production of high-power tubes made of quartz, and two sizes of each bulb are now being made, one for 25 kw. to the antenna, and another for 75 kw., but it is not expected that the efficiency of the high-power single units will be as good as that of the multiple units, and the work on the large tubes is being considered so far as experimental.

In transmission work a large amount of investigation has been carried out during the last two years on the efficiency of the circuits and in regard to the best way of utilizing the available energy.

Considerable increases in efficiency have been obtained in the aerial or antenna circuits and also in minimizing the losses in the attendant loading coils, and the latest results indicate that it is possible to obtain efficiency of radiation into space as high as fifty per cent on wave lengths as long as 20,000 meters, when, in this particular case, towers of a height of 250 meters would, of course, have to be used, owing to the length of the wave.

Very careful investigations have been carried out by Mr. H. W. Round of all the losses in the loading coils and other parts of the tube circuits, and actual measurements on considerable power have shown that an overall efficiency from the input power on the plates of the tubes to the aerial of 70 per cent is possible with a complete avoidance of harmonics, that is, an efficiency from the power input to the plates of the tubes to actual radiation into space of about 35 per cent.

On shorter wave stations it is quite practicable still further to increase this efficiency, although possibly it is hardly worth the extra expense involved. We have at present one station in England working on a 3000-meter wave length with a height of mast of 100 meters which has an efficiency from plates to radiation into space of 40 per cent.

Aside from the question of efficiency, great attention has been paid to maintaining an extremely constant frequency, and this can now be guaranteed to an extraordinary degree of constancy. Simple and reliable methods of high-speed keying have been developed which on the shorter waves can be used up to over 200 words per minute, and on the longer waves to whatever speed the aerial constants will permit.

In high-speed transmission, we are maintaining public services at 100 words per minute to two places in Europe namely, Paris and Berne, using a single aerial transmitter with two wave lengths on the same aerial, and although the operation of utilizing a single aerial for two wave lengths is not an advisable one for high-power work, it has certain points to recommend it in medium-power work, where the consequent loss of efficiency can be made up for by a slight increase of power.

These two waves are working duplex to both Paris and Berne and practically all traffic is taken on printing machinery, although there are occasions when, because of static reception has to be done on undulator tape, and in some rare cases, on the telephones, by sound.

The reception at these shorter distance stations is carried out by means of a cascade arrangement of high- and low-frequency-tuned amplifier circuits attached to the directional aerial system of the Bellini type, arranged for unidirectional reception when necessary. Very great care is taken in the receiving circuits to shield them so that the tuned circuits come well into action and to prevent any direct effect or influence of the aerial on circuits other than those intended to be acted upon. The characteristics of all these circuits have been very accurately measured so as to give filter curves suitable to the required speeds of working and the adjustments are easily performed by the operators. Aside from the protection from interference given by directional reception, a close filtering, and an element of saturation, no particularly sensational method or ideas in regard to static elimination have been so far introduced into practise.

The careful measurement and study of the constants of all circuits in use and the design of more efficient circuits from the result of those measurements is being systematically carried out, but as a result of these investigations considerable improvements have suggested themselves, which will be applied in the future if certain appropriate means can be devised.

The protection of receivers against the troubles of atmospherics or static can only be, and is likely to continue to be a relative matter, as it is quite obvious that a static eliminator under certain conditions will cease to be effective, where the static arrives with much greater intensity than had been anticipated and will also frequently fail when, in consequence of the weakness of the received signals, amplification has to be increased to any considerable extent.

It would be really interesting to know how much the increase in C. W. transmitters, the development in directional reception and the improvement in tuning that has taken place during the last few years, have really increased our speed of readability and reliability over given distances.

As the development has been gradual, the t ndency is toward pessimism, but I think, we are now able at the same expense to work at about 8 to 10 times the effective speed that we were able to work at in 1912 under the same atmospheric conditions.

Interference from other stations has, of course, enormously increased and this has perhaps somewhat checked the increase of speed, but fortunately prevention of interference from other radio stations is a very much easier problem than the prevention of the disturbances caused by natural electric waves, or static.

Amongst the different types of tube amplifiers used in modern radio receiving stations, the tuned high-frequency and audio-frequency amplifier is probably the one which excites the greatest technical interest. In fact, its selective qualities, combined with the comparatively better ratio of signal strength to interference which it secures, justifies such interest.

These advantages were fully realized by most radio workers during the war, and I do not think that at the time the armistice was signed there remained many radio laboratories where some time had not been utilized in experimenting on that type of receiver.

If those researches were generally not quite successful in regard to preparing or fixing the design of practical apparatus, they however, indicated that the main difficulty to be overcome was to combine considerable amplification with stability and that the solution of the problem became rapidly more difficult with the increase of the number of tubes used in cascade.

By stability, in this case, I mean the freedom from any sudden generation of oscillations in any part of the circuits of the amplifier.

In 1920, however, an important step was made by Mr. G. Mathieu, as to the path to be followed out in order to obtain a practical solution of the problem. This consisted in the design of a new type of air-core tuned intervalve transformer arranged in such a manner as to possess only an extremely small electrostatic capacity between the windings, and having its effective primary impedance about equal to the effective internal plate-to-filament resistance of the tube in use when the secondary circuit was brought into resonance with the frequency of the oscillations to be amplified.

The results achieved during the first tests of these new transformers appeared to be quite amazing, the amplification factor for one tube having passed suddenly from 5 to about 15 for the particular tube tested, whilst the stability proved incomparably better than had been obtained previously, even when the grid of the tube was kept to a negative potential of one or two volts.

The same principle has proved quite as successful when applied to the design of iron-core low-frequency

transformers. In this case, however, it was found necessary to adopt an iron magnetic shunt between the windings so as to provide a sufficiently loose coupling between the primary and secondary circuits of the transformer. Recently, Mr. Mathieu has further improved the design of his high-frequency transformer by making it astatic.

One of these new appliances including high-frequency and low-frequency-tuned transformers has been used daily on my yacht during my trip from England to America and the results of the tests carried out on board fully confirm the reliability of the apparatus and its marked superiority over the ordinary type of amplifier.

It has been clearly realized by most radio workers for some years that the science of radiotelegraphy had reached a stage of development where mere guesswork had done nearly all that could be expected from it, and that the improvement and development of commercial telegraphic services over what we once considered exceedingly long distances necessitated some very definite knowledge on the following points:

1. The strength of signals that can be relied upon with given arrangements over these distances, and

2. The all-important question of the ratio of the strength of signals to that of the natural disturbances and interferences acting on the receiving station in various parts of the world.

First of all, suitable and reliable apparatus for the purpose of obtaining the necessary data on both these points had to be developed. This apparatus is now in systematic daily use in a good many far distant places, with the result that a vast amount of most valuable information is being collected, and is now coming to hand.

At these observation points, the signals from distant stations are measured at all times of the day and night, together with the strength of the interference of static, and also the direction or bearing from which the static appears to be coming.

The measurements are done in such a way that the power that would be required at the transmitting station to give readability is used as a measure of the static, as this is the actual thing a radio engineer requires for the proper calculation of his transmitting station.

It is a method which gives a very satisfactory and reliable result in practise, and which I think could well be used universally.

In short this method consists in inducing in the aerial C. W. signals from the measuring apparatus, which signals are made equal to those received from the distant transmitting station. The voltage applied to the aerial can then be directly read off. An aerial of a standard size is used for the purpose, and from this the strength of the signals in microvolts per meter can be calculated. If the signals are then unreadable due to static, the measuring apparatus is used to send to an operator at a standard rate of 20 words per minute, 5-letter code, and the voltage applied to the aerial from the local sender is increased until complete readability is obtained, thus the ratio of the new voltage applied to the aerial to that of the old voltage equal to that of the signals received gives at once a very correct estimate of how much the power of the transmitting station would have to be increased in order to insure readability. As this variation can be carried out on aerial systems giving direction diagrams the method is obviously of great practical utility.

The question as to whether it would or would not be possible to transmit radio signals right around the world as far as the Antipodes is one which has always fascinated me. In fact the distance to the Antipodes is the greatest possible useful distance that can be covered by radio on this little earth of ours, and from this point of view the question was also important as such a distance included all minor distances between all other places on earth.

Sixteen years ago at a lecture I delivered on the 3rd of March, 1905, before the Royal Institution in London I expressed the belief that if it were proved that transmission to the Antipodes were possible, the waves ought to go over and travel around different parts of the globe from one station to the other, and perhaps all converge and concentrate at the Antipodes, and in this way I thought it might be possible to send messages to such distant places by utilizing only a moderate amount of electrical energy; and at that lecture I also showed a model globe and tried to explain how I thought the waves would help each other if arriving in proper phase, or in other words, concentrate at places at or near the Antipodes of the sending station.

The results recently obtained and which go to show the relative facility with which radio signals can now be sent from England to Australia seems to indicate that there is someting in the idea of the wireless waves traveling around the earth by various ways and reuniting at places near the Antipodes.

But still more interesting and precise data have been obtained during other more recent tests.

Two expeditions, one to Brazil, and the other to New Zealand have carried out a number of most interesting and instructive observations, and although complete reports have not yet been received, I think it will nevertheless be of interest if I give you the results of some of their important tests.

The expedition to Brazil of which Mr. H. H. Beverage of the Radio Corporation of America, Mr. N. W. Rust, of the Marconi Wireless Telegraph Co. of England, and Mr. W. Eichkoff and Dr. A. Esau of the Gesellschaft fur Drahtlose Telegraphie (Telefunken) of Berlin formed part, has just completed a series of observations at various points on the Atlantic Coast of South America, where the intensity of the signals from European and other stations has been observed and measured at all times of the day and night, and where also the direction and intensity of atmospherics or static has been

equally observed and recorded over considerable periods of time.

Another expedition under the direction of Mr. E. Tremellen, of the English Marconi Company, has just completed its work in measuring signals from all European and American high power stations, on a journey between England and New Zealand via the Panama Canal, and from the mass of information obtained on both day and night signals it should be possible among other things, to reconstruct the attenuation formula. Incidentally, I may say that the signals exceed greatly in strength what should be expected according to the Austin-Cohen formul , otherwise super-long-distance working would not be a practi al proposition.

Complete measurements from England to the Antipodes have been made on the Carnavon, Nauen, Bordeaux, and Hanover signals; and also in Brazil on the American high-power stations and on the U. S. Naval Station, N. P. O. at Cavite (Philippine Islands).

In both these expeditions to Brazil and New Zealand the fact has been noted definitely and independently, and I think for the first time that signals from stations at very great distances do not always retain their direction along one great circle, but reach the receiver from either way or various ways around the earth.

These important observations were made by means of loop aerial direction finders arranged so as to give the well-known heart-shape diagram and the very interesting fact has been recorded independently by both expeditions, that on many occasions during what might be called a transition period, when the wave is changing from one way round the earth to another way round, the two or more sets of waves when received on a simple vertical aerial produced fairly slow beats resembling Morse signals, caused by the mutual interference or addition of the two sets of waves, whereas on the direction finder heart-shape diagram arrangement, the signals were quite steady and normal when it was turned so as to receive only from one way or the other.

Of course it should be noted that when one is very near to the Antipodes there is only such a slight difference between any of the great circles leading from the sending station that the constancy of direction is not maintained but this direction seemed to keep definitely true at distances of about 2000 miles from the Antipodes.

The observers noted American signals from Radio Central and from Tuckerton coming from a direction which indicated that they preferred to travel a distance of three quarters of the way around the earth, rather than come by the shortest way round. Also, according to the reports received from the observers on other occasions at or near the Antipodes of the English or German stations, the direction finder often indicated the signals as coming from directions all around.

Another interesting and rather extraordinary result was noted on several occasions, according to the report of Mr. Tremellen from Rocky Point, New Zealand, where during last March the signals from Nauen appeared to travel to him via the South Pole, whilst those from Hanover, also situated in Germany, and not very far from Nauen, appeared to prefer to travel via the North Pole.

A much more complete and exhaustive series of observations at fixed stations in Australia is now being made so as to obtain if possible all the variations from one period of the year to the other.

It seems to have been definitely ascertained in a general way that the sources of bad atmospheric disturbances, or static, are situated chiefly over land, but observations in Brazil indicate that a type of static known as "grinder" is a disturbance originating a long way off and coming from a direction which indicates the African Coast and at a time of day when static there would be at a maximum, whereas a very violent "click" type of static came from a direction indicating its source as being nearby in South America.

During my present journey across the Atlantic, on board the yacht *Elettra*, we noticed that up to about half way across (apart from the effects of local storms) static interference appeared to be coming mainly from the European and African continents while at more than half way across they were coming from Westerly directions, that is, from the American continent.

The changing over of the direction of origin of these disturbances has also been noted under similar circumstances by Mr. Tremellen in crossing the Pacific.

It is very fortunate for the North Atlantic Trans-Atlantic radio service, carried out at stations in North America, and Europe, particularly for those in Western Europe, that this strong nearby type of static comes from directions which greatly differ from those from which one has to receive, and that the continents which lie in the direction of the sending stations are so far distant and sufficiently temperate as not to project troublesome static to the receiving stations on the other side of the ocean.

Another fact which can be fairly well deduced from these tests over very great distances is that transmission from West to East is apparently easier than from East to West, and shows the necessity for qualifying or modifying the transmission formula for great distances.

A scientific paper giving the results of measurements and of all the work carried out and observations made in these two expeditions will shortly be published.

I shall now deal with another and most important branch of the science of radiotelegraphy; a branch which I might say has been for a long time most sadly neglected. It concerns the use that can be made of very short waves, especially in regard to their application to directional radiotelegraphy and radiotelephony.

Some years ago, during the war, I could not help feeling that we had perhaps got ten rather into a rut by confining practically all our researches and tests to what I may term long waves or waves of some thou-

sands of feet in length, especially as I remembered that during my very early experiments, as far back as 1895 and 1896, I had obtained some promising results with waves not more than a few inches long.

The study of short waves dates from the time of the discovery of electric waves themselves, that is, from the time of the classical experiments of Hertz and his contemporaries, for Hertz used short electric waves in all his experiments, and also made use of reflectors to prove their characteristics and to show, among many other things, that the waves, which he had discovered, obeyed the ordinary optical laws of reflection.

As I have already stated, short electric waves were also the first with which I experimented in the very early stages of wireless history, and I might perhaps recall the fact that when, over 26 years ago, I first

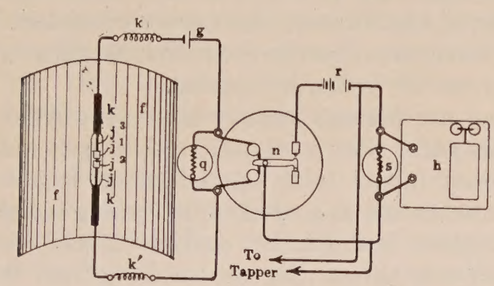

Fig. 2—Early Short Wave Directional Receiver

went to England, I was able to show to the late Sir William Preece, then Engineer-in-Chief of the British Post Office, the transmission and reception of intelligible signals over a distance of 1¾ miles by means of short waves and reflectors (Figs. 2 and 3) while, curiously enough by means of the antenna or elevated wire system, I could only get, at that time, signals over a distance of half a mile.

The progress made with the long wave or antenna system, was so rapid, so comparatively easy, and so spectacular, that it distracted practically all attention and research from the short waves, and this I think was regrettable, for there are very many problems that can be solved, and numerous most useful results to be obtained by, and only by, the use of the short-wave system.

Sir William Preece described my early tests at a meeting of the British Association for the Advancement of Science, in September 1896, and also at a lecture he delivered before the Royal Institution in London on the 4th of June, 1897.

On the 3rd of March, 1899, I went into the matter more fully in a paper I read before the Institution of Electrical Engineers in London, to which paper I would call your attention as being of some historical interest.

At that lecture I showed how it was possible, by means of short waves and reflectors, to project the rays in a beam in one direction only, instead of allowing them to spread all around in such a way that they could not affect any receiver which happened to be out of the angle of propagation of the beam.

I also described tests carried out in transmitting a beam of reflected waves across country over Salisbury Plain in England, and pointed out the possible utility of such a system if applied to lighthouses and lightships, so as to enable vessels in foggy weather to locate dangerous points around the coasts.

I also showed results obtained by a reflected beam of waves projected across the lecture room, and how a receiver could be actuated and a bell rung only when the aperture of the sending reflector was directed towards the receiver.

Since these early tests of over twenty years ago practically no research work was carried out or published in regard to short waves, so far as I can ascertain, for a very long period of years.

Research along these lines did not appear easy or promising; the use of reflectors of reasonable dimensions implied the use of waves of only a few meters in length which were difficult to produce, and, up to a comparatively recent date, the power that could be utilized by them was small. This, and the fact of the very high attenuation of such waves over any distance of land or sea, gave results which appeared to be very disappointing.

The investigation of the subject was again taken up by me in Italy early in 1916 with the idea of utilizing very short waves combined with reflectors for certain war purposes, and at subsequent tests during that year, and afterwards, I was most valuably assisted by Mr. C. S. Franklin, of the British Marconi Company.

Mr. Franklin has since then followed up the subject with great thoroughness and the results obtained have

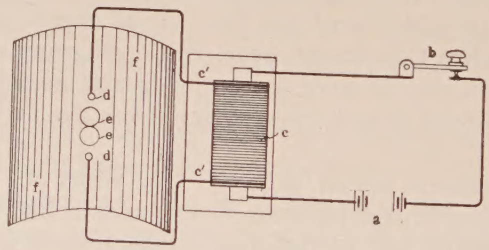

Fig. 3—Early Short Wave Directional Transmitter

been described by him in a paper read before the Institution of Electrical Engineers in London on the 3rd of April, 1922.

Most of the facts and results which I propose to bring to your notice are taken from Mr. Franklin's paper.

The work carried out in experimenting with these waves in 1916, was most interesting, as it was like going back to the very early days of wireless, when one had a perfectly clear field.

The waves used had lengths of two meters and three meters. With these waves, disturbances caused by static can be said to be almost non-existent, and the

only interference experienced came from the ignition apparatus of automobiles and motor boats. These machines apparently emit electric waves from near zero to about 40 meters in length, and the day may come when they will perhaps have to have their ignition systems screened, or carry a Government license for transmitting.

Incidentally I might mention that one of these short wave receivers will act as an excellent device for testing, even from a distance, whether or not one's ignition is working all right. Some motorists would have a shock if they realized how often their magnetos and sparking plugs are working in a deplorably irregular manner.

During my tests in 1916, I used a coupled spark transmitter, the primary having an air condenser and spark in compressed air. By these means the amount of energy was increased and the small spark gap in compressed air appeared to have a very low resistance.

The receiver at first used was a crystal receiver, while the reflectors employed were made of a number of strips or wires tuned to the wave used, arranged on cylindrical parabolic curve with the aerial in the local line.

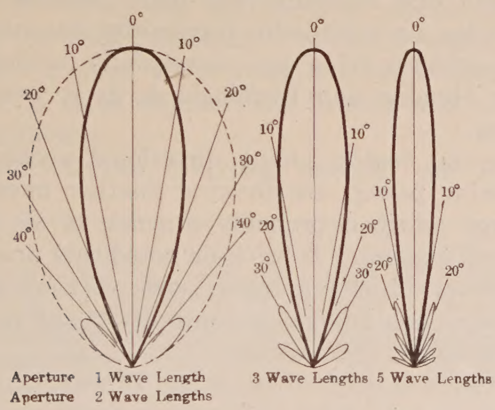

FIG. 4—CALCULATED POLAR CURVES OF REFLECTORS

The transmitting reflector was arranged so that it could be revolved and the effects studied at a distance on the receiver.

Mr. Franklin has calculated the polar curve of radiation into space (Fig. 4), in the horizontal plane, which should be obtained from reflectors of various apertures, by assuming that the waves leave the reflector as plane waves of uniform intensity, having a width equal to the aperture of the reflector. The calculated curves agree very well with the observed results. In Fig. 4 are shown the calculated curves for reflectors having apertures equal to 1, 2, 3 and 5 wave lengths.

Reflectors with apertures up to 3½ wave lengths were tested, and the measured polar curves agreed very well indeed with the calculated values.

The Italian experiments showed that good directional working could always be obtained with reflectors properly proportioned in respect to the wave length employed, and with the apparatus then available the range obtained was six miles.

The tests were continued in England at Carnarvon during 1917. With an improved compressed air spark gap transmitter, a three-meter wave, and a reflector having an aperture of two wave lengths and a height of 1.5 wave lengths, a range of over 20 miles was

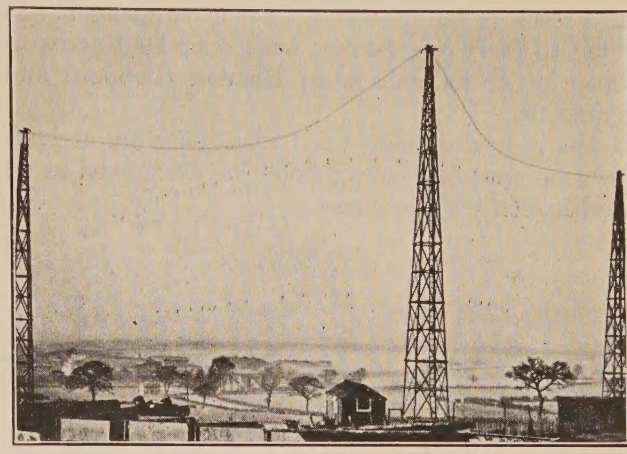

FIG. 5—DIRECTIONAL TRANSMITTER (HENDON)

readily obtained with a receiver used without a reflector.

In 1919 further experiments were commenced by Mr. Franklin at Carnarvon for which electron tubes or valves were used to generate these very short waves, the object being to evolve a directional radiotelephonic system.

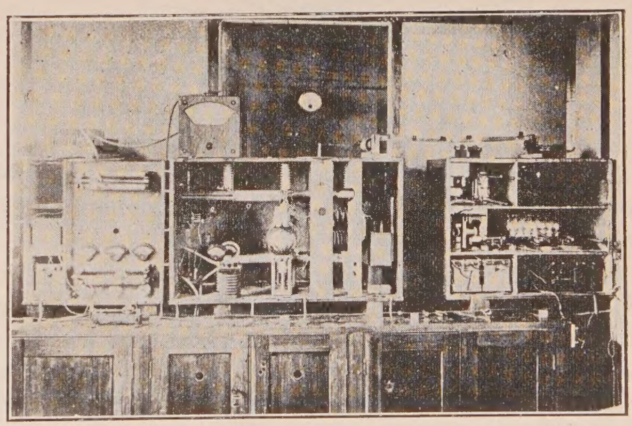

FIG. 6—EXPERIMENTAL SHORT WAVE TRANSMITTER AND RECEIVER AT HENDON

A 15-meter wave was chosen, which could quite easily be generated by the type of electron tube employed.

After overcoming a few practical difficulties, very strong and clear speech was received at Holyhead 20 miles away. Longer-distance tests were next undertaken and a receiving set of apparatus was installed

on one of the mail boats running between England and Ireland.

During these tests clear speech was received all the way over to the Irish coast and into Kingstown Harbor at a distance of 78 miles from Carnarvon. The important fact was also noticed that there was no rapid diminution of the strength of signals after the ship had passed the horizon line from Carnarvon.

As a result of the success of these experiments it was decided to carry out further tests over land across a distance of 97 miles between Hendon (London) and Birmingham.

It was proved at once that, with reflectors at both ends, good and clear speech could be exchanged at all times between the two places.

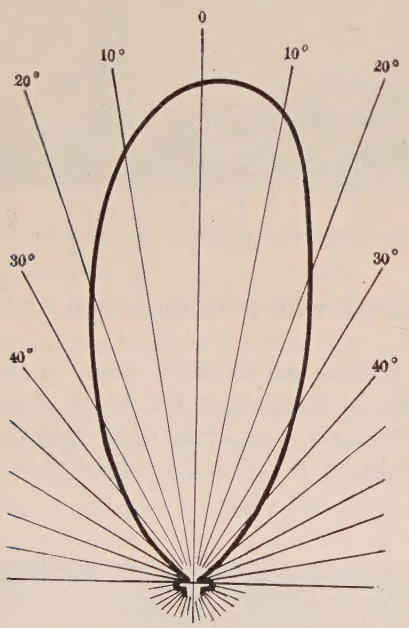

Fig. 7—Polar Curve of Hendon Reflector

The following are some particulars of the arrangements employed at Hendon and at Birmingham (Figs. 5 and 6).

The power supplied to the tubes employed is usually 700 watts. The aerial is rather longer than half a wave length and has a radiation resistance which is exceedingly high. The efficiency input to the tubes to aerial power is between 50 and 60 per cent, and about 300 watts are actually radiated into space.

With the reflectors in use at both ends, speech is strong and of very good quality. It is usually strong enough to be just audible with a ¼- to ½-ohm shunt across a 60-ohm telephone.

With both reflectors down and out of use, speech is only just audible with no shunt. Average measurements made by Mr. Franklin indicate that the value of the energy received when both reflectors are used is about 200 times that of the energy received without any reflectors.

These figures have been lately confirmed by local measurements taken round the stations.

Fig. 7 shows a measured polar curve of the field of Hendon station taken in the vicinity of the reflector. It is rather unsymmetrical in consequence perhaps of the ground being on a slope, and owing to local reflection from trees and wires.

It has occurred to some of my assistants that a polar curve taken locally round the station may not be the same as a curve taken at a distance, and that at a distance the directional effect may be lost. I am, however, in agreement with Mr. Franklin that such is not the case.

Experiments carried out with revolving reflectors, which make it easy to read measurements at any distance, prove that the polar diagram for a given reflector and wave length is practically constant at all ranges.

By means of suitable electron tubes or valves, it is now quite practicable to produce waves from about 12 meters and upwards utilizing a power of several kilowatts, and it is also practicable to utilize valves in parallel.

During the continuous wave tests at Carnarvon, it was found that reception was quite possible on the transmitting aerial while the transmitter was operating.

This system is being used successfully for duplexing between Hendon and Birmingham, as it avoids all switching.

Reflectors, besides giving directional working, and economizing power, are showing another unexpected advantage, which is probably common to all sharply directional systems. It has been noted that practically no distortion of speech takes place, such as is often noticed with non-directional transmitters and receivers even when using short waves.

The results between Hendon and Birmingham easily constitute a record for radiotelephony in respect to the ratio of distance to wave length, as Birmingham, it may be interesting to note, is 10,400 wave lengths from Hendon.

We consider, however, that these results represent only what could be obtained from a first attempt, and not what could now be done after the experience gained.

It has thus been shown for the first time that electric waves of the order of 15 to 20 meters in length, are quite capable of providing a good and reliable point to point directional service over quite considerable ranges.

In these days of broadcasting, it may still be very useful to have a practically new system which will be to a very large degree secret, when compared to the usual kind of radio.

The results obtained by reflectors appeared to be so good that I was tempted to try out my old idea of 26 years ago, and test the system as a position finder for ships near dangerous points. This is now being done

in Scotland through the courtesy of Messrs. D. and C. Stevenson and of the Commissioners of Northern Lights. Trials are being carried out under the supervision of Mr. Franklin with a revolving reflector erected at Inchkeith Island in the Firth of Forth near Edinburgh. The transmitter and reflector revolving,

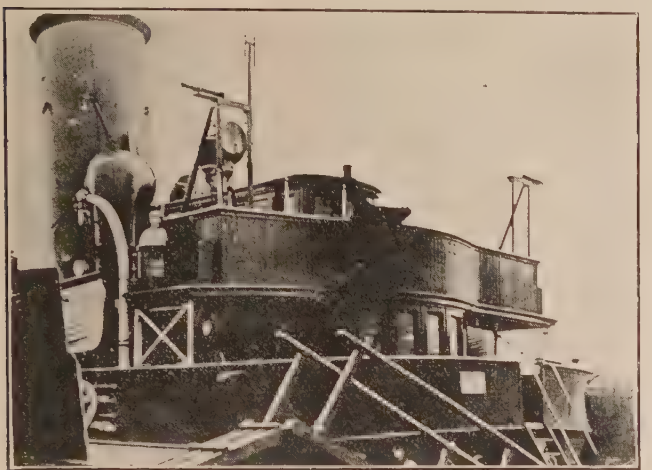

Fig. 8—Short Wave Receiver on Steamship "Pharos"

act as a kind of wireless lighthouse or beacon, and, by means of the revolving beam of electrical radiation, it is possible for ships, when within a certain distance to ascertain, in thick weather, the bearing and position of the lighthouse.

The experimental revolving reflector was erected

Fig. 9—Short Wave Receiver

and the first tests were carried out with the S. S. *Pharos* during the autumn of 1920 (Fig. 8).

With a 4-meter wave spark transmitter, a reflector, and a single tube receiver, suitably tuned, on the ship, a working range of seven miles was obtained.

The reflector was caused to make a complete revolution every two minutes, and a distinctive signal was sent every half point of the compass. It was ascertained on the steamer that this enabled the bearing of the transmitter to be accurately determined within ¼ point of the compass, or within 2.8 degrees. At a later date a new reflector was designed and erected and is now being tested (Fig. 12).

Figure 10 shows measured polar curves taken

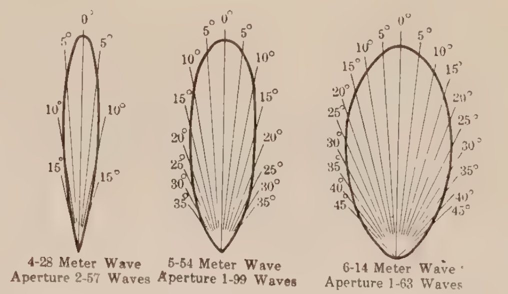

Fig. 10—Polar Curves of Inchkeith Reflector

recently with the new reflector. The curves were measured at a distance of 4 miles.

With the revolving beam, the exact times of maximum signals are not easy to judge, by ear, but the times of starting and vanishing are easy to determine, as the rate of rise and fall of the signals is extremely rapid. The time half way between these two times gives, with great exactness, the moment when the beam is pointing to the ship (Fig. 11).

By means of a clockwork arrangement a distinctive letter is sent out every two points, and short signs mark intermediate points and half points; and this is

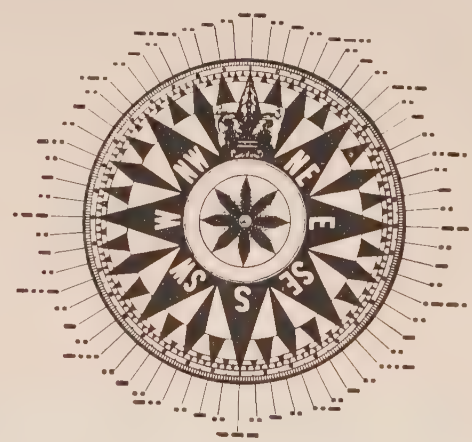

Fig. 11—Compass Bearings with Letter Designations for Radio Direction Finding

done in practice by contact segments arranged on the base of the revolving reflector, so that a definite and distinctive signal is transmitted at every half or quarter point of the compass (Fig. 12).

I will now try to show you the working of a roughly constructed 1-meter wave transmitter and reflector.

The attenuation of these short waves over sea is so surprisingly regular that a little experience enables distance to be judged by the strength of signals, and this can be measured by means of a potentiometer.

Before I conclude I should like to refer to another

possible application of these waves which, if successful, would be of great value to navigators.

As was first shown by Hertz, electric waves can be completely reflected by conducting bodies. In some of my tests I have noticed the effects of reflection and deflection of these waves by metallic objects miles away.

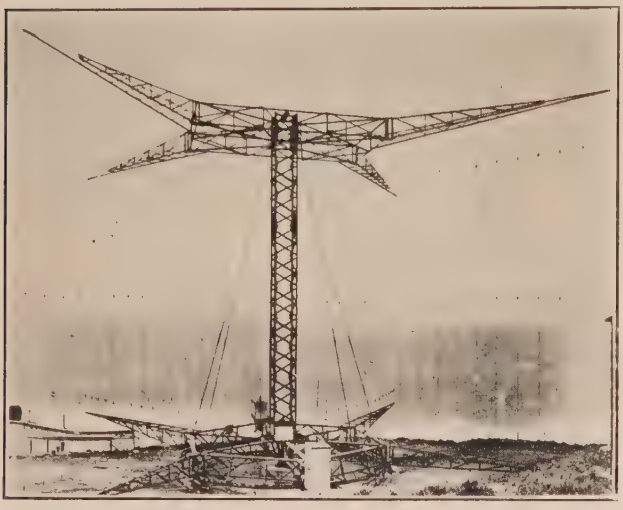

Fig. 12—Rotating Short-Wave Directional Transmitter, Inchkeith

It seems to me that it should be possible to design apparatus by means of which a ship could radiate or project a divergent beam of these rays in any desired direction, which rays, if coming across a metallic object, such as another steamer or ship, would be reflected back to a receiver screened from the local transmitter on the sending ship, and thereby immediately reveal the presence and bearing of the other ship in fog or thick weather.

One further great advantage of such an arrangement would be that it would be able to give warning of the presence and bearing of ships, even should these ships be unprovided with any kind of radio.

I have brought these results and ideas to your notice as I feel—and perhaps you will agree with me—that the study of short electric waves although sadly neglected practically all through the history of wireless, is still likely to develop in many unexpected directions, and open up new fields of profitable research.

Having referred so lengthily to what is essentially a directional system, that is, a system that does not spread its waves all round, you will perhaps expect a few words from me before I bring this rather lengthy discourse to a close, on the subject of "Broadcasting."

No remarks from me or from anyone else are required to tell you what has already been done with radio in America, as a means of broadcasting human speech, and other kinds of sound which may also be entertaining if not always instructive.

In thousands of homes in this country there are radiotelephonic receivers, and intelligent people, young and old, well able to use them—often able to make them and in many instances contributing valuable information to the general body of knowledge concerning the problems great and small of radiotelegraphy and radiotelephony.

But I think I am safe in saying that if radio has already done so much for the safety of life at sea, for commerce, and for commercial and military communications, it is also destined to bring new and, until recently, unforeseen opportunities for healthy recreation and instruction into the lives of millions of human beings.

Engineering Graduates in Business

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In a business in which engineering talent is required to produce its output or operate its plants, the engineering graduate is looked to as the supply of timber from which to build up the personnel of the technical and supervisory forces. Without a capable personnel no organization can be effective, and without knowledge such as the engineer is trained to use in an accurate way, no such business can make headway against its competitors.

The engineering graduate has been trained in the fundamentals of pure science and mathematics, and has been given an acquaintance with applied sciences which, if he has been conscientious, has provided for him the foundation of his future work. He is started in his first position as a draughtsman, inspector, laboratory assistant, tester, or in some similar line of work where he will be able to render service of some value while he is learning enough about the business to fit him for a position of responsibility. In some cases he may be shifted from one minor job to another several times before he is definitely placed. In other cases he may voluntarily shift from one business to another in the hope of finding something which looks more promising. In this process he discovers work for which he has an aptitude and in most cases the work is of a specialized nature in which he makes use of but a small part of the knowledge gained in school. The result is that those whose natural talents qualify them to excel at highly

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technical kinds of work are chosen promptly for such work, giving the impression that the highly technical man is the one most sought after and desired.

A considerable part of the men who entered with a given class and whose talents run rather to construction and installation work, or to sales engineering, have either fallen by the wayside under the discouragement of the tests encountered, or, if graduated, have drifted away after a time into some other line of activity where their talents are better appreciated. Men of the latter class may be and often are those having business ability, and after the first few years they are likely to be found in positions of greater responsibility than those whose ability as students was much more marked. Every class of any large engineering school which has been out of school for five to ten years affords examples of this.

There are, of course, the exceptional men who were good students and had also the talents for the larger positions in life, and these exceptions but prove the rule.

Thus in the past decade there has been a distinct tendency to develop a large body of engineering technicians who are highly skilled in the treatment of special problems and who have as a result contributed in a large way to the sum of human knowledge. But too many of these men have become so highly specialized that they have lost the breadth of view which is essential to a proper sense of perspective and are, therefore, incapable of seeing the broader problems of industry or of suggesting solutions for them.

Now, how is a recital of conditions affecting graduates of engineering schools in past years related to the education and training of the coming generation? The answer is that history will repeat itself unless changes are made in the general scheme of education in the future.

The training of the student has been conducted thus far from the point of view of giving him a general fund of technical knowledge. This is perhaps only the natural result of an atmosphere where scholarship is made the chief criterion of excellence, and other lines of ability are largely subordinated to it.

The training of the students of the future should make provision for the type of men who though they may not shine in technical work will nevertheless take places of importance in the industrial world where leadership, salesmanship, and executive ability are in great demand.

It is true that men of this type will usually make a place for themselves in the world whether they enter engineering schools or not, but the engineering world is losing many men under present conditions whom it will very much need in the coming years.

The engineering courses as at present constructed appear to be unattractive to this type of men and we find many of the sons of graduates of the last generation substituting courses in general science for engineering courses in order to get more of the general culture of a college training, and to come more into touch with the the non-technical life of the school.

Just how the details of engineering courses should be modified to make them more attractive to this class of students I do not presume to say, but it would seem that the elective courses could have a broader scope and the required work could be made less exacting than has been the custom in most schools.

The situation may be likened in many respects to the conduct of a saw mill enterprise, conducted by a lumber company which is cutting its own timber. The business is covering the rough pine lumber market for general construction purposes and its mill and other facilities have been planned for this business exclusively. It turns out heavy timber for railroad and mill construction and smaller shapes for building purposes and general uses. Its supply of timber is chiefly pine, but there are occasionally "stands" of certain kinds of hardwood which yield logs of higher value than the general run of pine, and though a few of these come through with the rest, the majority are left standing. The mill is not equipped to handle these few properly for the hardwood market, so they go into the output and are sold with the pine. The consumer finding these occasional pieces of hardwood is not able to take advantage of their increased value and they are hidden in a structure where their worth is not likely to be recognized by the owner. Occasionally it is true such a piece comes to the attention of a foreman by chance, and after proper seasoning and finishing operations is given a place befitting its value. After a time, the mill owners realize they are losing a valuable part of their output, and provide for proper finishing of their hardwood as it passes through. It is thereafter turned out in such shape that it can be seasoned and finished for the more important uses to which it is adapted. This makes it possible for the lumber company to take the hardwood with the pine, thus clearing up the entire stand of available timber as it goes.

The available timber entering the universities and engineering schools has many things in common with the stand of timber described in the foregoing illustration.

If technical experts are to be the chief output of the schools the timber which doesn't make good ones will be and is being eliminated as it goes through. And if perchance a few exceptional men get through who are capable of being more than technicians, they are as likely as not to become buried in the technical work so deeply that the fact that they are capable of greater responsibilities is not discovered until a long time after it should have been known.

The establishment of a course designed for treating the hardwood, that is, the men who do not aim to take positions where the work is highly technical, will perhaps not result in any output of men of any higher average ability than are graduated from other courses, but it should serve to increase the available supply of timber for general uses, for which there is now a firm demand with a diminishing supply.

Potential Gradient In Cables

Discussion of the Logarithmic Formula, Its Modification and Effect of Internal Heat

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Review of the Subject.—*If the dielectric of a single-conductor concentric cable is homogeneous, the voltage gradient at any diameter x is given by*

$$\frac{d\,v}{d\,x} = \frac{0.868\,V}{x \log_{10} \dfrac{D}{d}}.$$

where $\frac{d\,v}{d\,x}$ *is the voltage gradient or dielectric stress, V the voltage between conductor and sheath, D the diameter over the dielectric and d the diameter over the conductor.*

A complete discussion of the above formula is followed by considerable experimental data and curves accumulated from many breakdown tests.

Results of tests on cables with large ratios of dielectric diameter to conductor diameter are included and a modification of the above theoretical formula is discussed. The modified formula is checked by tests on a special cable which was constructed for this purpose.

A new relation between the rupturing gradient at the surface of the conductor and the ratio D/d is suggested and curves of experimental data given.

Breakdown tests on three-conductor cables are included and the calculated rupturing stresses compared with those for single-conductor cables.

Special cables were constructed so that measurements could be made of voltages between layers of insulation. From data obtained from these tests, curves are given showing the change in potential gradient as the internal heat of the cable is increased. Curves are given showing the effect of a change of temperature on the dielectric strength, the stresses and the factor of safety of cables.

A complete description is given of the low-capacitance electrostatic voltmeter used in the temperature-potential-gradient tests.

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Review of the Subject. (270 w.)
Introduction. (860 w.)
Cables having Constant Outside Diameters but Varying Conductor Diameters. (1000 w.)
Cables having Constant Conductor Diameters but Varying Outside Diameters. (350 w.)
Effect of Stress on permittivity. (900 w.)
Law of Breakdown for Values of D/d greater than 2.72. (975 w.)
Stresses in Three-Conductor Cables. (2000 w.)
Effect of Internal Heating on Voltage Gradient within Concentric Insulation. (2100 w.)
Conclusions. (400 w.)

Introduction

In a paper presented before the Institute in 1914[1] two of the authors gave the relations of testing voltage to the allowable stress and to the geometry of cables. The rules and constants given at that time were the results of data and experience covering a number of years. Since that time we have been conducting numerous experiments in order to determine more specifically the relations which exist among the maximum allowable gradients, the applied voltage and the geometry of cables. Tests have also been conducted to determine the effect of the conductor heating on the potential gradients in cables.

It should be appreciated that it is not a simple matter to determine the laws governing the breakdown voltage of dielectrics because the results are usually so erratic. The breakdown voltage for various sections cut from the most carefully made cable varies over wide limits even under the same conditions of test, owing to the fact that it is practically impossible to make homogeneous insulation. When a weak spot yields to the stress, more stress is immediately concentrated on the remaining layers, and the cable punctures. This action is cumulative and tends to produce erratic results, even under the best of conditions. The breakdown voltage is also a function of the rate of application of voltage, length of cable tested, etc. We have taken every precaution to prevent inconsistent results, by raising the potential at the same rate in every case, by using the same lengths of cable, and by taking the average of at least five readings for each test.

We are presenting the results obtained from numerous experiments and indicating the laws which breakdowns, etc., appear to follow in these tests. We do not claim that these laws are final, but on the contrary we feel that considerable more data must be obtained before any such laws can be accepted as final. In order to conduct a series of tests which will give satisfactory results, a large number of cables having the same dielectric, but with fixed outside diameters and variable conductor diameters, and also cables with fixed conductor diameters and variable outside diameters must be carefully made and tested. The fact that this involves considerable time and expense has prevented more data of this character being obtained.

If the dielectric of a single-conductor concentric cable is homogeneous, the voltage gradient at any diameter x is given by

$$\frac{d\,v}{d\,x} = \frac{0.868\,V}{x \log_{10} \dfrac{D}{d}} = S \qquad (1)$$

where S is the dielectric stress or potential gradient, V the voltage between conductor and sheath, D the diameter of the dielectric, and d the conductor diameter.

1. W. I. Middleton and Chester L. Dawes "Voltage Testing of Cables," Trans. A. I. E. E., Vol. XXXIII (1914), page 1185.

Presented at the Annual Convention of the A. I. E. E., Niagara Falls, Ont., June 26-30, 1922.

If x is expressed in mils, S is given in volts per mil. The stress is obviously a maximum at the surface of the conductor, where $x = d$. If the conductor diameter d, is small as compared with D, the stress S at the surface of the conductor will be large, even with a thick

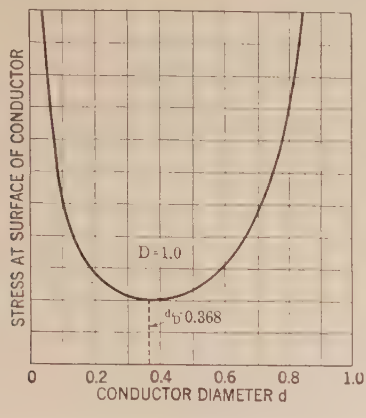

FIG. 1—RELATION BETWEEN STRESS AT SURFACE OF CONDUCTOR AND CONDUCTOR DIAMETER

Impressed voltage and insulation diameter fixed.

wall of insulation, owing to the concentration of the dielectric flux at the conductor surface. As the diameter of the conductor d increases, D and V remaining fixed, S at first decreases, because of the less concentration of dielectric flux with increasing conductor diameter. When $d = D/2.72$, where 2.72 is the Napierian logarithmic base, S becomes a minimum. The gradient then increases with further increase in d, owing to the lesser thickness of the wall of the dielectric. The relation of the gradient S at the surface of the conductor and the ratio of the conductor to the dielectric diameter for fixed values of V and D is shown in Fig. 1. The minimum gradient occurs when $d/D = 0.368 = 1/2.72$. The curve, however, is quite

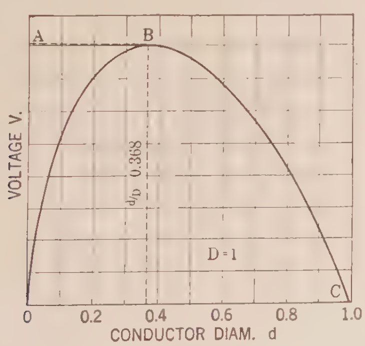

FIG. 2—RELATION BETWEEN ALLOWABLE VOLTAGE AND CONDUCTOR DIAMETER

Maximum stress and insulation diameter fixed.

flat near the point of minimum gradient. Obviously, S is infinite when $d = O$, and when $d = D$.

If the allowable gradient S at the surface of the conductor and the diameter of the dielectric D, be maintained constant, the voltage which may be impressed on the cable

$$V = \frac{S}{0.868}\, d \log_{10} \frac{D}{d} = 1.15\; S\, d \log_{10} \frac{D}{d} \qquad (2)$$

Fig. 2 shows the relation between V and d, with S and D (= 1.0) fixed. The maximum voltage which may be impressed under these conditions, and yet not overstress the dielectric at any point, occurs when $D/d = 2.72$ or when $d/D = 0.368$. The voltage V is obviously zero when $d = O$ and when $d = D$.

When D/d is equal to or less than 2.72, equations (1) and (2) are generally accepted for determining the voltage, the stress, etc. Our experience has always been that these equations give very consistent results. When D/d exceeds 2.72, however, the layers of insulation adjacent to the conductor can be subjected to gradients far in excess of those which the insulation can normally withstand and yet complete rupture does not occur because the gradient in the remaining layers is not sufficient to cause them to rupture.

We have subjected rubber to dielectric stresses three and four times the value at which it normally ruptures by applying voltage to cables having a very small conductor diameter.

The applied voltage was sufficiently high to produce high stresses in the rubber adjacent to the conductor, and yet not rupture the cable. Examination under a high-powered microscope of the rubber after being subjected to these stresses for considerable time, failed to reveal any change in the physical structure of the dielectric.

CABLES HAVING CONSTANT OUTSIDE DIAMETERS BUT VARYING CONDUCTOR DIAMETERS

In order to investigate the effect of large ratios of dielectric to conductor diameters on dielectric stresses we had several special cables made up. It was necessary to make these of rubber as it is difficult to use wrapped insulations, such as paper and cambric, with the small conductor diameters which we used. Moreover, rubber is a more homogeneous dielectric than either of the other two.

The first two sets of cables were made with the object of determining the effect upon breakdown voltage of having a constant outside diameter and variable conductor diameter. The outside diameters were 12/32 in. or 375 mils (9.49 mm.).

With a gaseous dielectric and concentric cylinders having diameter ratios exceeding 2.72, the dielectric at the surface of the inner conductor becomes ionized when the voltage gradient at its surface becomes sufficiently high. This produces corona at the surface of the inner conductor, and its effective diameter is increased by corona formation, as is well-known. Theoretically, this can occur until the corona diameter equals $D/2.72$, when complete rupture occurs without further increase of voltage. These effects will be modified somewhat by the ionization of the air outside the corona diameter.

So far as we know, this effect can only occur in solid

dielectrics when there are pockets of occluded gases, and even then the effect cannot be large. In well-made cables we feel that the effect of corona formation on stress distribution is negligible.

Assume that the values of V given by curve $O\ B\ C$, Fig. 2, produce a gradient at the surface of the conductor equal to the disruptive strength of the dielectric. When the impressed voltage exceeds the values given by the portion $O\ B$ of the curve, the dielectric near the conductor is obviously stressed beyond its disruptive strength. So far as the writers know, corona cannot form in such a manner as to increase the effective diameter of the conductor. Many theories as to the effects which this condition of overstress produces in the dielectric have been advanced, such as the carbonizing of the dielectric, etc.

In the cables constructed for investigating this effect, conductors ranging from No. 24 A. W. G. giving a value of D/d = 18.65 to No. 3 Stranded (A. W. G.) giving a value of D/d = 1.44 were used. Breakdown tests were made on short lengths, the results of which are tabulated in Table I.

TABLE I.

Set No. 1. D = 12/32 in. = 0.375 in. (9.49 mm.)

Size cond. A. W. G.	Cond. diam. (d) mils	Ratio D/d	Ratio d/D	Break-down voltage	Gradient at cond. surface volts per mil
24 solid	20.1	18.65	0.0536	27,680	942
20	32.0	11.70	0.0853	29,480	748
14	65.0	5.77	0.173	33,940	592
..	90.0	4.17	0.240	35,280	549
8	128.0	2.93	0.342	39,140	568
6	162.0	2.31	0.432	33,490	493
5	186.0	2.02	0.496	31,760	487
2	258.0	1.45	0.688	23,830	494
3 strd.	260.0	1.44	0.694	27,950	587

The insulation showed a dielectric strength of approximately 500 volts per mil when D/d was less than 2.72.

The values of breakdown voltage given in Table I

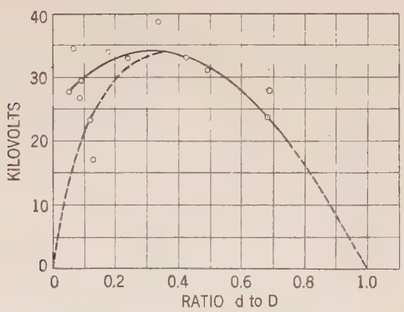

Fig. 3—Relation between Rupturing Voltage and the Ratio of Conductor to Insulation Diameters for Data in Table I.

Full line—actual breakdown
Dotted line—calculated breakdown
Maximum stress—500 V/mil

are plotted as kilovolts in Fig. 3, with the ratio d/D as abscissas. With two exceptions, the points lie on a smooth curve. The dotted curve shows the voltage which will give a constant gradient of 500 volts per mil at the surface of the conductor, as the conductor diameter varies. It will be noticed that the two curves coincide, over the range of experiment, for values of

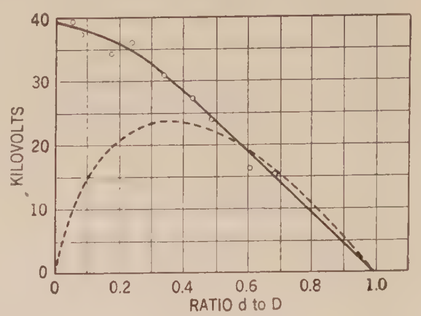

Fig. 4—Relation between Rupturing Voltage and the Ratio of Conductor to Insulation Diameters for Data in Table II

Full line—actual breakdown
Dotted line—calculated breakdown
Maximum stress—347 V/mil

d/D greater than 0.368 or 1/2.72. When the value of d/D is less than 0.368 the breakdown curve departs from the constant gradient curve, lying well above it. If the insulation loses its dielectric strength as soon as it becomes overstressed, the breakdown voltage should follow the curve $A\ B\ C$, Fig. 2, as was pointed out by the authors in their 1915 paper[2].

Our experience that the breakdown voltage usually followed the straight line $A\ B$ more closely than the the curve $O\ B$, Fig. 2, led us to adopt the following formula for cables having conductor diameters less than $D/2.72$

$$S = \frac{0.868\ V}{d_c \log_{10} \frac{D}{d_c}} = \frac{5.44\ V}{D} \qquad (3)$$

where $d_c = \dfrac{D}{2.72}$

TABLE II.

Set No. 2. D = 12/32 in. = 0.375 in. (9.49 mm.)

Size cond. A. W. G.	Cond. diam. (d) mils	Ratio D/d	Ratio d/D	Break-down voltage	Gradient at cond. surface volts per mil
24 solid	20.1	18.65	0.0536	39,940	1355
20	32.0	11.70	0.0853	38,250	971
14	65.0	5.77	0.1732	34,900	612
..	90.0	4.17	0.240	36,760	571
8	128.0	2.93	0.342	31,630	460
6	162.0	2.31	0.432	26,870	395
5	186.0	2.02	0.496	23,980	368
3	229.0	1.637	0.610	16,750	297
2	258.0	1.453	0.688	15,720	326

The cables whose breakdown characteristics are given in Table I and Fig. 3 follow this law very closely. The breakdown voltage actually becomes less when the conductor diameter becomes less than $D/2.72$, showing

2. loc. cit.

that the insulation between the conductor and the diameter $D/2.72$ adds nothing to the dielectric strength of these particular cables, but rather causes it to be less.

Table II gives data on another set of cables (No.2), similar to that shown in Table I. These cables were made of rubber having very nearly the same composition as that used in No. 1, but were cured by a different method.

Fig. 4 gives the relation between d/D and breakdown voltage for this set of cables. The dotted curve is calculated on the basis of 347 volts per mil, the average of the gradients at the conductor surfaces for the last four cables, whose ratio of outside to conductor diameter was less then 2.72.

Although the dielectric of these cables is nearly the same as that of set No. 2, except for cure, this set of cables has markedly different dielectric characteristics. The dielectric stress calculated for large values of d/D is only about 0.7 that for the first set of cables and yet with small values of d/D it has much greater dielectric strength. That is equation (3) is not applicable to these cables. A comparison of the results obtained with these two cables demonstrates the difficulty of obtaining consistent results under all conditions.

Cables Having Constant Conductor Diameters but Varying Outside Diameters

In order to determine the effect on the dielectric strength of cables of increasing the wall of insulation with a fixed conductor diameter, another set of cables was made up. In this set a No. 24 A. W. G. conductor having a diameter of 20.1 mils (0.51 mm.) was used. The diameters of the insulation varied from 3/32 in. (2.38 mm.) to 10/32 in. (7.94 mm.) giving values of D/d ranging from 4.69 to 15.55.

The results obtained with these two sets of cables were used to determine the breakdown constant K of the insulation.

Dividing equation (1) by 0.868 gives

$$1.15\,S = K = \frac{V}{d \log \dfrac{D}{d}} \tag{4}$$

This equation is used to calculate K when D/d is less than 2.72. When D/d is greater than 2.72 equation (3) is likewise used.

$$K = \frac{V}{d_c \log \dfrac{D}{d_c}} = \frac{6.27V}{D} \tag{5}$$

The constant K is the dielectric strength of the insulation multiplied by the constant 1.15. If the breakdown voltage follows these laws the values of K obtained by using equations (4) and (5) should be practically constant. As the values of D/d for all the cables in Table III were greater than 2.72, only equation (5) was used in the computation of K, for these particular cables.

TABLE III.

Set No. 3—No. 24 A. W. G. Cond. Diam. (d) = 20.1 mils (0.510 mm.)

Outside diam.	Ratio D/d	Breakdown voltage	k
3/32 in.	4.69	9,930	663
4/32	6.22	13,600	681
5/32	7.77	17,800	715
6/32	9.33	23,000	769
8/32	12.45	27,300	685
10/32	15.55	34,200	685

The values of K calculated, using equation (5) and given in Table III, are plotted in Fig. 5.

With small values of D/d, K increases slightly. For large values of D/d, K is practically constant. The breakdown voltage of this set of cables followed the law given by equations (4) and (5) very closely.

Effect of Stress on Permittivity

It is well-known that the dielectric constant or permittivity of a dielectric increases under dielectric stress. We felt that this fact might offer a partial explanation, at least, of the ability of the inner layers of cables to withstand voltage gradients far in excess of the normal rupturing gradients of the dielectric, and yet apparently show no signs of rupture.

If the capacitance of that part of the cable nearer the conductor increased a sufficient amount, there would obviously be a less percentage of the total voltage across these layers under high stress, hence the cable would automatically grade itself.

To determine whether or not there was any considerable change of capacitance under these conditions, a special cable was made up. The dimensions and cross-section of this cable are shown in Fig. 6. Our idea was to make a cable having a very heavy wall of insulation and also an extremely high value of D/d. Between the conductor and outside, a concentric conducting cylinder was made into the cable as a means of determining the potential at some intermediate distance

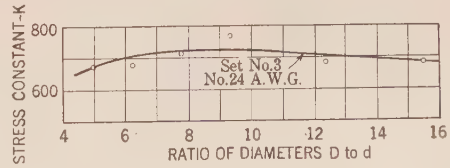

Fig. 5—Relation between Stress Constant K and the Ratio of Insulation and Conductor Diameters for Cables in Table III

between the conductor and the outer surface of the insulation. Because of greater ease of manufacture, a 0.038-in. (0.97 mm.) lead sheath was used for this intermediate conducting cylinder. The copper was No. 12 A. W. G. having a diameter of 0.081-in. (2.06

mm.). The inside diameter of the lead was 0.328 in. (8.34 mm.) giving 4.05 as the value of D/d for this inside portion of the cable. This value of D/d is well above the critical value of 2.72 and any phenomena developing under these conditions should be apparent

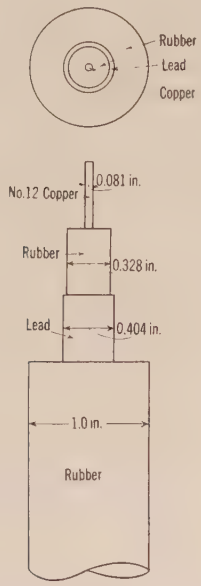

Fig. 6—Cable with Intermediate Sheath

in this cable. The outer diameter of the lead was 0.404 in. (10.3 mm.) and the cable diameter was 1.0 in. (25.4 mm.) giving 2.48 as the value of D/d for this outer portion of the cable. The ratio of outside to conductor diameter is only slightly less than the critical value of 2.72.

Approximately 100-ft. lengths of this cable were immersed in water. The electrostatic capacitance was then measured with low-voltage, 25-cycle, alternating current by means of a deflecting dynamometer, the cable capacitance being obtained by direct comparison with a standard condenser.

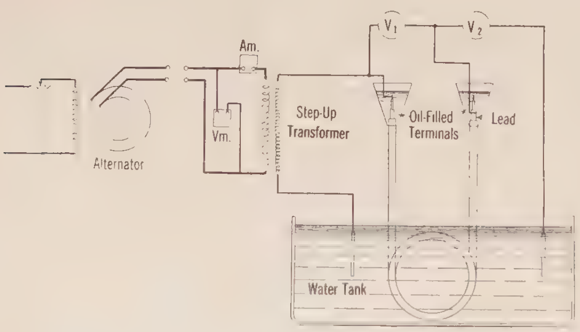

Fig. 7—Diagram of Connections for Stress Tests on Cable with Intermediate sheath

The cable was then connected to the secondary of a step-up transformer, the connections being shown in Fig. 7. The potential difference between the copper and lead and that between lead and ground was measured by means of two vibrating electrostatic voltmeters V_1 and V_2, a description of which has already been published by one of the authors.[3] The capacitance of these instruments is practically nil as compared with the capacitances across which they were connected, hence they did not disturb the potential relations within the cable.

Fig. 8 gives the results obtained from a typical test. The voltage, copper to lead and lead to ground, are plotted as ordinates with the total voltage from copper to ground as abscissas. The ratios between these two voltages remained practically constant until the voltage from copper to lead reached 22 kv. when there was a noticeable unsteadiness in the vibrations of both electrostatic instruments. As the applied voltage was being increased, the unsteadiness of V_1 became pronounced and at 22.8 kv. its reading dropped to zero, showing that the insulation between copper and lead had ruptured. Simultaneously, the reading of V_2 jumped to that corresponding to line voltage.

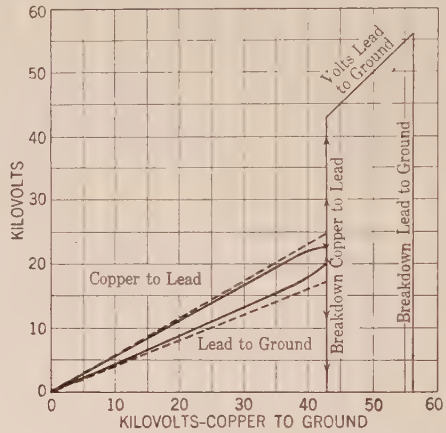

Fig. 8—Relation between Potentials—Copper to Intermediate Sheath, Intermediate Sheath to Ground, and Copper to Ground

Full lines—experimental values
Dotted lines—calculated values

The voltage was then raised slowly until at 56.5 kv. the cable punctured from lead to ground. At the instant of breakdown between copper and lead the stress at the surface of the conductor was 600 volts per mil. Using equation (3), the stress at the diameter $D/2.72$ was 377 volts per mil. The stress at the surface of the lead when the entire cable broke down at 56.5 kv. was 308 volts per mil. Three tests similar to the above were made, and the cable broke down copper to lead at practically this same voltage, the voltages being 23.8 kv. and 26.0 kv. In the subsequent tests the breakdown voltages from lead to ground were much higher than 56.5 kv., the average being approximately 70 kv.

The voltage between copper and lead and that from lead to ground were then calculated, using the measured values of alternating-current capacitance. The cal-

3. Trans. A. I. E. E., Vol. XXXV (1916), page 133.

culated voltages are shown by the dotted lines, Fig. 8. It will be noted that the increase of capacitance of the inner portion of the cable, which was under high stress, over that of the outer portion of the cable, which was under only moderate stress, is only of the order of 5

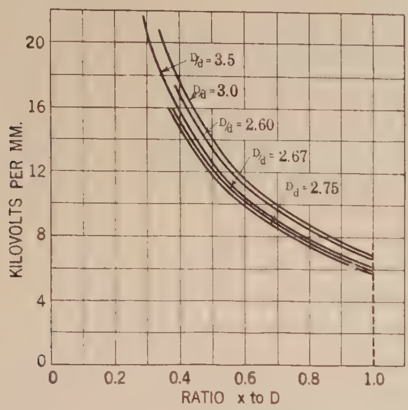

FIG. 9—RELATION BETWEEN GRADIENTS THROUGHOUT THE WALLS OF INSULATION AND THE RATIO x/D
Breakdown tests of F. Fernie.

per cent except at the instant of breakdown, when it is slightly greater than this. This 5 per cent change in capacitance agrees very closely with other measurements which we have made to determine the change of capacitance caused by electrostatic stress. We feel that these tests demonstrate that the stress across the inner layers of a cable having a large ratio D/d is not relieved to any considerable extent by a change of capacitance produced by the stress. It also demonstrates that for this particular cable, the wall of insulation within a diameter of $D/2.72$ adds nothing to the dielectric strength of the cable.

LAW OF BREAKDOWN FOR VALUES OF D/d GREATER THAN 2.72

As was stated earlier in the paper, our object in making these numerous tests was, if possible, to determine some relation between the breakdown voltage and the stresses within the insulation for large values of D/d.

In an article appearing recently in *Beama*,[4] F. Fernie submits test data showing that several different cables, tested by him, all rupture with practically equal potential gradients at the outer surface of the insulation. The results are tabulated in Table III of his paper. The authors have examined this paper very carefully. In checking his values of gradient given in the last column of Table III, we find several values in error. The values of stress calculated by us, using his data, are not so nearly equal as his figures indicate. However, even then the difference can be readily accounted for by the erratic nature of breakdown tests already discussed. Even if these cables did break down at values of gradient at the outer surface of the insulation which were practically equal, we do not feel that it is at all rational to consider the breakdown voltage a function of dielectric strength of the outer layers where the gradient is a minimum.

Fig. 9 shows the calculated gradient throughout the insulation of each cable at the instant of breakdown. The gradient is plotted with kv. per mm. as ordinates and values of x/D as abscissas for each cable, where x is any diameter within the insulation. With fixed values of d and D and homogeneous insulation, the stress at each diameter x is inversely proportional to x (Eq. (**1**)). Therefore, each of these curves is a rectangular hyperbola. That is, the gradient at each point of Curve 1, Fig. 9,

$$S_1 = \frac{K_1}{(x/D)} \tag{6}$$

and the stress at each point on curve 2

$$S_2 = \frac{K_2}{(x/D)} \tag{7}$$

where K_1 and K_2 are constants.

For any given value of x/D

$$S_1/S_2 = K_1/K_2 \tag{8}$$

That is, the ratio of ordinates of any two curves for each value of x/D is constant for all values of x/D. If the gradients at the outer surfaces of the insulation of two cables are equal, they will be equal at all values of x/D for the two cables. If cables break down for equal values of gradient in the outer layers, the gradients in the inner layers for each value of x/D, as far as a given curve extends, must be equal.

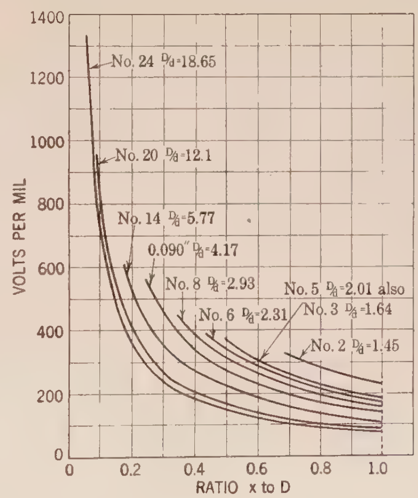

FIG. 10—RELATION BETWEEN GRADIENTS THROUGHOUT THE WALLS OF INSULATION AND THE RATIO x/D FOR CABLES IN TABLE II

An examination of Fig. 9 shows that the cables broke down for nearly equal values of gradient at the ratios of x to D between 0.33 and 0.39 which correspond practically to the critical ratio of D to d of 2.72.

We find that if the values of gradient at the outer surfaces of our cables No. 1 and No. 2 be plotted as

4. F. Fernie, "Insulation Experiments," *Beama* Sept. 1921 page 244.

ordinates and d/D as abscissas, in one case a perfectly straight line results, and in another the plot is slightly curved. We do not feel that this is important, however, as it is merely the result of higher gradients existing within the inner layers of the cable.

On analyzing the tests made on the sets of cables

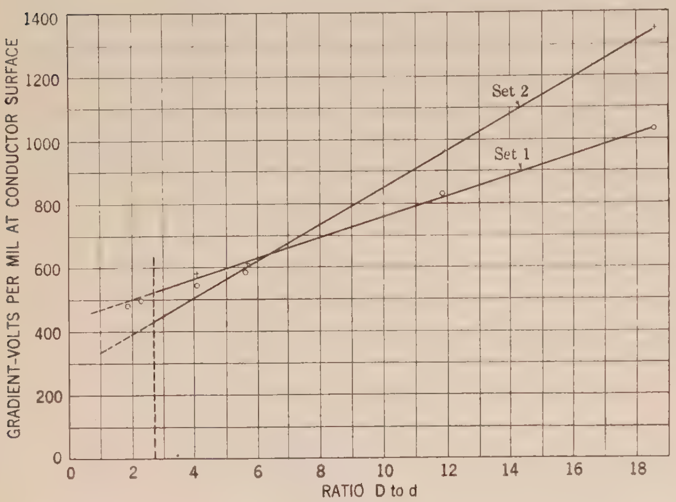

Fig. 11—Relation between Conductor Stress and Ratio of Insulation to Conductor Diameters for Cables in Tables I and II

No. 1 to No. 3 inclusive, the gradients throughout the insulation as ordinates and values of x/D as abscissas for each cable were plotted. A typical example for set No. 2 is shown in Fig. 10. The insulation is assumed homogeneous in every case.

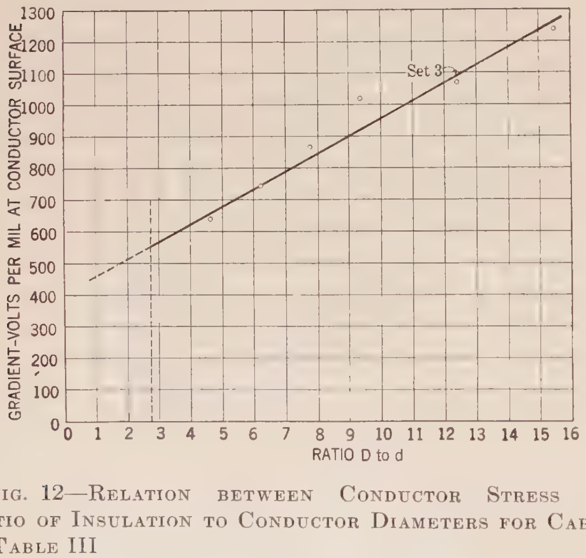

Fig. 12—Relation between Conductor Stress and Ratio of Insulation to Conductor Diameters for Cables in Table III

The upper extremity of each curve is the gradient at the conductor surface at the instant of breakdown. It will be noted that if a curve be drawn through these upper extremities, a curve resembling a rectangular hyperbola results. Therefore, if these gradients at the conductor surface be plotted with the reciprocal of d/D or D/d as ordinates, the plot should be nearly a straight line.

Fig. 11 shows these plots for the cables in sets No. 1 and No. 2. It will be noted that the points, particularly at the larger values of D/d, lie on practically a straight line. It should not be expected that every point will lie in a smooth curve, as, has already been pointed out, dielectric breakdown tests are certain to be more or less erratic. Each line, Fig. 11, intercepts the ordinate $D/d = 1.0$ at a value of gradient only very slightly less than the rupturing gradient of the respective dielectric of the set of cables which it represents.

The equation of these lines is obviously

$$S = K + A\,x \qquad (9)$$

where S is the gradient at the surface of the conductor at breakdown, K is the intercept on the S-axis, A is a constant and $x = D/d$.

Fig. 12 gives similar plots for the cables in set No. 3 having conductors of No. 24 A. W. G. and varying walls of insulation.

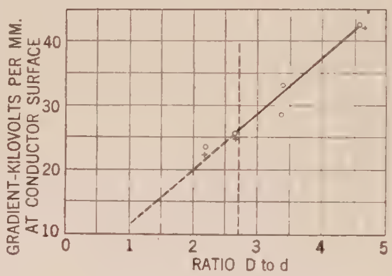

Fig. 13—Relation between Conductor Stress and Ratio of Insulation and Conductor Diameters for Cables in F. Fernie's Paper

Fig. 13 gives similar curves using values obtained from F. Fernies' paper.[5] The plot given by these points is a straight line within the precision of results obtained from any set of breakdown tests. The intercept on the ordinate $D/d = 1.0$ gives a value of gradient about 0.7 the rupturing gradient of the insulation.

All the test data which we have available seem to indicate that for any given dielectric a straight-line law exists between the gradient at the conductor surface at breakdown and the ratio of outside to conductor diameters (D/d) for values of D/d greater than 2.72. However, we feel that further investigation is needed along this line, before this relation be accepted as final.

Stresses in Three-Conductor Cables

At the present time, there are two common methods of calculating the maximum stress in a three-conductor cable.

In the first method, which is the one used by most engineers until recently, the maximum stress for a three-conductor cable was calculated by the same formula as that used for a single-conductor cable of the

5. loc. cit.

same size of conductor and having a wall of insulation equal to the total wall between the conductors of the three-conductor cable.

The second method is by means of a formula recently published in the JOURNAL and PROCEEDINGS of the A. I. E. E.[6] Here again the stress in a three-conductor cable is calculated by the same formula as for a single-conductor cable, but the wall of insulation is assumed to be equal to the distance between the conductor surface and the center of the three-conductor cable. A correction factor is involved, dependent upon the relation between the conductor insulation and the conductor diameter.

In order to determine which one of these two methods of calculating stress in a three-conductor cable was the more accurate, a series of breakdown tests was made on single- and three-conductor cables.

The rupturing stress for the insulation should be approximately the same with both the single and three-conductor cables.

Of the two foregoing methods, the one which should be accepted as standard is the one which gives the rupturing stress of the insulation of a three-conductor cable more nearly equal to that of a single-conductor cable, having the same kind of insulation.

Tables IV and V give the results of breakdown and calculated stresses for single and three-conductor paper cables.

TABLE IV.

Breakdown Tests—6-ft. Samples—No. 6 A. W. G.
PAPER

Cable	Sample	Breakdown Voltage Y	Breakdown Voltage △	d log D/d Method Old	d log D/d Method New	Max. stress Method Old	Max. stress Method New
Three-Cond., No. 6	1	15,000	25,900	85.6	65.2	263	200
St.—5/64-in. Wall	2	17,600	30,400			308	235
—5/64-in. Jacket	3	20,400	35,300			358	272
Three - Phase — 60	4	15,600	27,000			274	208
cycles	5	16,800	29,100			295	224
	6	17,200	29,800			302	229
	7	17,600	30,500			309	235
	8	23,000	39,800			403	307
	9	18,000	31,200			316	240
	10	18,800	32,500			329	251
				Average		316	240
Three-Cond., No. 6	1	21,400	37,000	85.6	65.2	375	285
St.—5/64-in. Wall	2	19,600	33,900			343	261
—No Jacket	3	17,600	30,500			309	235
Three - Phase — 60	4	20,000	34,600			351	266
cycles	5	15,800	27,300			277	211
	6	19,600	33,900			343	261
	7	18,200	31,500			319	243
				Average		331	252
Single-Cond., No. 6	1	49,600		80.6		534	
St.—5/32-in. Wall	2	37,200				402	
Single - Phase — 60	3	36,800				396	
cycles	4	24,800				267	
	5	31,200				336	
	6	33,200				357	
	7	30,000				323	
	8	37,200				402	
	9	36,000				388	
	10	28,000				301	
				Average		371	

6. R. W. Atkinson, "The Dielectric Field in an Electric Power Cable," TRANS. A. I. E. E. Vol. XXXVIII (1919), page 971. Davis & Simons, "Maximum Allowable Working Voltages in Cables," A. I. E. E. JOURNAL, January 1921.

Table VI gives the results of breakdown and calculated stress for single-conductor and three-conductor varnished cambric cables.

TABLE V.

Breakdown Test 6 ft. Samples—No. 2 A. W. G. Paper.

Cable	Sample	Breakdown Voltage Y	Breakdown Voltage △	d log D/d Method Old	d log D/d Method New	Max. stress Method Old	Max. stress Method New
Three-Cond., No. 2	1	22,800	38,600	99.4	77.7	338	255
St.—5/64-in. Wall	2	21,600	37,300			326	241
—5/64-in. Jacket	3	26,800	46,300			405	300
Three - Phase — 60	4	18,800	32,500			284	210
cycles	5	21,800	37,700			330	244
	6	31,000	50,500			432	346
	7	19,200	33,200			291	215
	8	35,000	60,500			529	391
	9	24,600	42,500			372	275
	10	20,600	35,600			311	230
				Average		362	271
Single-Cond., No. 2	1	31,200		87.3		310	
St.—5/32-in. Wall	2	40,800				406	
Single - Phase — 60	3	31,600				314	
cycles	4	30,800				306	
	5	27,600				274	
	6	33,800				336	
	7	42,800				426	
	8	30,400				302	
	9	28,800				286	
	10	36,000				358	
				Average		332	

The breakdowns were all made at 60 cycles and by raising the voltage at the rate of approximately 1000 volts per second. The single-conductor cables were broken down with single-phase voltage between conductor and lead and the three-conductor cables with three-phase voltage between conductors, the lead sheath being grounded and connected to the neutral point of the Y-connected transformers.

TABLE VI.

Breakdown Tests—6-Ft. Samples—No. 6 A. W. G.
CAMBRIC

Cable	Sample	Breakdown Voltage Y	Breakdown Voltage △	d log D/d Method Old	d log D/d Method New	Max. stress Method Old	Max. stress Method New
Three-Cond., No. 6	1	25,000	43,300	84.0	64.0	448	339
St.—5/64-in. Wall	2	22,000	38,100			393	298
—5/64-in. Jacket	3	27,000	46,700			482	366
Three - Phase — 60	4	25,000	43,300			447	339
cycles	5	27,000	46,700			482	366
	6	24,000	41,600			430	326
	7	24,000	41,600			430	326
	8	21,600	37,400			386	293
	9	23,200	40,200			415	314
	10	26,000	45,000			465	353
				Average		438	332
Three-Cond., No. 6	1	24,600	42,600	84.0	64.0	440	334
St.—5/64-in. Wall	2	25,000	43,300			447	339
—No Jacket	3	18,800	32,500			336	255
Three - Phase — 60	4	30,000	51,900			537	407
cycles	5	22,400	38,800			402	304
	6	24,600	42,600			440	334
	7	28,000	48,500			502	380
	8	22,600	39,100			404	306
	9	29,000	50,200			517	393
	10	20,800	36,000			372	282
				Average		440	333
Single-Cond., No. 6	1	47,200		79.0		518	
St.—5/32-in. Wall	2	43,600				480	
Single - Phase — 60	3	47,000				516	
cycles	4	48,800				537	
	5	50,000				550	
	6	41,600				457	
				Average		510	

TABLE VII.

1000-Cycle Capacitance Tests—Paper

Copper temp.		68°F = 20°C	105°F = 40.5°C	148°F = 64.5°C	175°F = 79.5°C	200°F = 93.3°C
Lead temp.		68°F = 20°C	78°F = 25.5°C	94°F = 34.5°C	105°F = 40.5°C	113°F = 45.0°C
Copper	No. 1 Layer	3720	3940	3965	4020	4140
No. 1 Layer	No. 2 Layer	2910	2940	3000	3050	3110
No. 2 "	No. 3 "	3770	3875	3840	3870	3900
No. 3 "	No. 4 "	5530	5550	5560	5610	5640
No. 4 "	Lead	5560	5590	5590	5840	5900

TABLE VIII.

1000-Cycle Capacitance Test—Cambric Sample

Copper temp.		71°F = 21.7°C	99°F = 37.2°C	148°F = 64.5°C	175°F = 79.5°C	200°F = 93.3°C
Lead temp.		71°F = 21.7°C	80°F = 26.7°C	101°F = 38.3°C	115°F = 46.1°C	121°F = 49.4°C
Copper	No. 1 Layer	3075	3230	3530	3690	3750
No. 1 Layer	No. 2 "	4540	4730	5170	5220	5320
No. 2 "	No. 3 "	4650	4780	5020	5050	5080
No. 3 "	No. 4 "	6310	6450	6730	6850	6850
No. 4 "	Lead	7300	7450	7770	8000	8030

TABLE IX.

Measured Voltages—Grounded Lead Sheath to Layers of Copper Strands
Paper Cable

Copper temp.	68°F = 20°C	105°F = 40.5°C	148°F = 64.5°C	175°F = 79.5°C	200°F = 93.3°C
Lead temp.	68°F = 20°C	78°F = 25.5°C	94°F = 34.5°C	105°F = 40.5°C	113°F = 45.0°C
Lead to Copper	10,000	10,000	10,000	10,000	10,000
" No. 1 Layer	7,900	8,000	8,050	8,110	8,250
" No. 2 "	5,140	5,200	5,250	5,400	5,550
" No. 3 "	2,980	3,000	3,000	3,100	3,250
" No. 4 "	1,480	1,500	1,490	1,500	1,550

TABLE X.

Measured Voltages—Grounded Lead Sheath to Layer of Copper Strands
Cambric Cable

Copper temp.	71°F = 21.7°C	99°F = 37.2°C	148°F = 64.5°C	175°F = 79.5°C	200°F = 93.3°C
Lead temp.	71°F = 21.7°C	80°F = 26.7°C	101°F = 38.3°C	115°F = 46.1°C	121°F = 49.4°C
Lead to Copper	10,000	10,000	10,000	10,000	10,000
" No. 1 Layer	6,950	7,000	7,100	7,200	7,350
" No. 2 "	4,900	5,000	5,200	5,400	5,650
" No. 3 "	2,950	3,000	3,100	3,350	3,500
" No. 4 "	1,400	1,400	1,450	1,600	1,650

TABLE XI.

Voltage Between Successive Layers—Paper Sample

Copper temp.		68°F = 20.0°C	105°F = 40.5°C	148°F = 64.5°C	175°F = 79.5°C	200°F = 93.3°C
Lead temp.		68°F = 20.0°C	78°F = 25.5°C	94°F = 34.5°C	105°F = 40.5°C	113°F = 45°C
Copper	No. 1	2100	2000	1950	1900	1750
No. 1 Layer	No. 2 Layer	2760	2800	2800	2700	2700
No. 2 "	No. 3 "	2160	2200	2250	2300	2300
No. 3 "	No. 4 "	1500	1500	1510	1600	1700
No. 4 "	Lead	1480	1500	1490	1500	1550

TABLE XII.

Voltages Between Successive Layers—Cambric Sample

Copper temp.		71°F = 21.7°C	99°F = 37.2°C	148°F = 64.5°C	175°F = 79.5°C	200°F = 93.3°C
Lead temp.		71°F = 21.7°C	80°F = 26.7°C	101°F = 38.3°C	115°F = 46.1°C	121°F = 49.4°C
Copper	No. 1	3050	3000	2900	2800	2650
No. 1 Layer	No. 2 Layer	2050	2000	1900	1800	1700
No. 2 "	No. 3 "	1950	2000	2100	2050	2150
No. 3 "	No. 4 "	1550	1600	1650	1750	1850
No. 4 "	Lead	1400	1400	1450	1600	1650

It should be noted that the rupturing stresses of the three-conductor cables when calculated by the old method are nearly the same as for the single-conductor

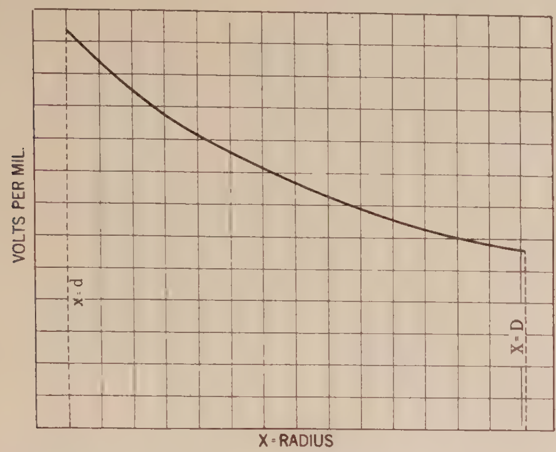

Fig. 14—Typical Potential-Gradient Curve

cables, while the stresses calculated by the new method are considerably lower.

Effect of Internal Heating on Voltage Gradient within Concentric Insulation

The general shape of the potential gradient or stress curve for a homogeneous wall of concentric insulation calculated by the logarithmic formula, equation (**1**), is shown in Fig. 14.

If the wall of insulation is not homogeneous, but made up of multiple layers of insulating materials having different dielectric constants, the voltage distribution throughout the wall may be calculated by the formula

$$V_0 = V_1 + V_2 + V_3 + \ldots V_n$$

$$= \frac{2Q}{K_1} \log_e r_1/r + \frac{2Q}{K_2} \log_e r_2/r_1 + \frac{2Q}{K_3} \log_e r_3/r_2 + \ldots \quad (10)$$

$$\frac{2Q}{K_n} \log_e r_n/r_{n-1}$$

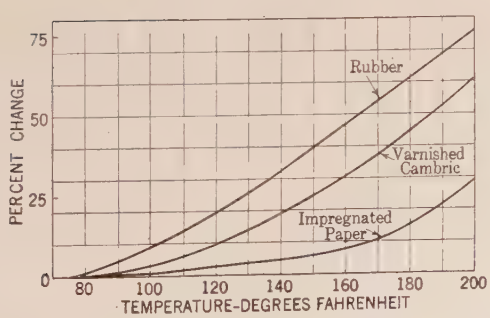

Fig. 15—Per Cent Change of Dielectric Constant with Change of Temperature for Insulating Materials

where V_0 is the total voltage across the wall of insulation

V_1, V_2, V_3 are the respective voltages across the first, second, third layers of insulating material

Q is the electrostatic charge on the surface of each layer of insulating material

K_1, K_2, K_3 are the respective dielectric constants of the layers of insulating material

r is the radius of the conductor

r_1, r_2, r_3, . . . r_n are the radii of the layers of insulating material.

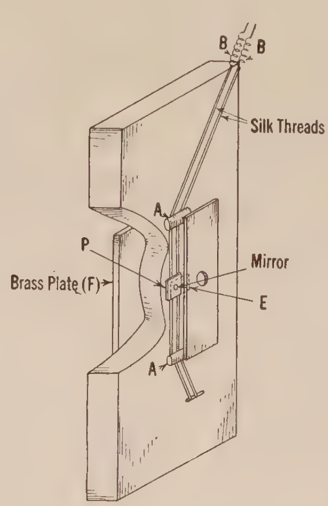

Fig. 16—Low-Capacitance Electrostatic Voltmeter

By employing multiple layers of insulating materials with the proper relative values of dielectric constants, it is possible to reduce considerably the maximum voltage stress at the surface of the conductor and increase the stresses in the outer layers of the insulation.

This method of insulating cables is commonly referred to as "grading" and theoretically results in a

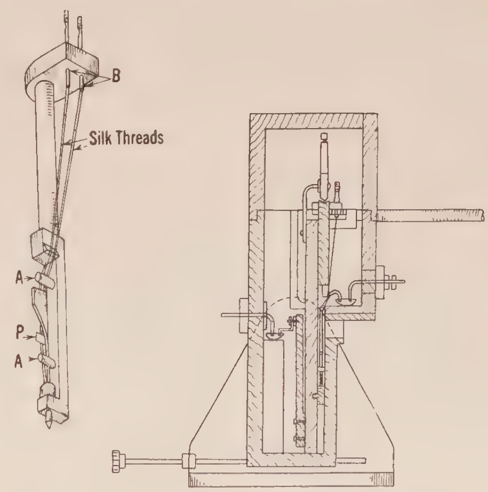

Fig. 17—Low-Capacitance Electrostatic Voltmeter

cable that will withstand a higher impressed voltage than a non-graded cable, other factors being equal.

Several excellent papers[7] have been published on the subject of "grading of cables."

7. E. Jona, *Trans. of International Elec. Congress*, St. Louis, 1904, page 550.
A. Russel, *London Electrician*, Vol. 60, 1907, page 160.
H. S. Osborne, Trans. A. I. E. E., Vol. 29, 1910, page 1553.

An insulated cable carrying current must dissipate energy in the form of heat, and the source of this energy is the $I^2 R$ loss in the conductor. The heat flows from the conductor to the surrounding medium with the result that the conductor is at a much higher temperature than the outside of the insulation.

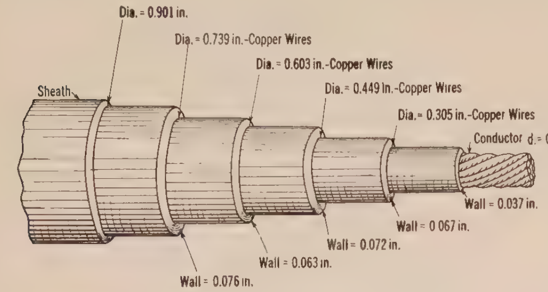

Fig. 18—Dimensions of No. 4 Stranded Paper-insulated Stress Sample

The dielectric constant of insulating materials increases very considerably with increase of temperature. In Fig. 15 there are curves showing the average increase of dielectric constants with temperature for the three most common cable insulating materials.

Therefore, theoretically, the insulation nearest the conductor of a cable carrying current should have a higher dielectric constant than the insulation farther from the center with the result that the voltage distribution throughout the wall of insulation should change as the temperature increases.

The following tests were made to determine whether or not the voltage distribution followed the theoretical law, and if so, how much change occurred as the temperature was increased.

The instrument used for voltage measurements was a modification of one described by Prof. C. L. Dawes in a discussion on voltage measurements at New York in 1916.[8]

Figs. 16 and 17 show the general scheme of the voltmeter.

Two silk threads are stretched tightly between two supports *A A*, the proper tension being secured by the springs *B B*. A thin brass plate (*P*) approximately 6 by 11 millimeters is cemented at one end to the two silk threads half way between the supports. On this brass plate is a small mirror for reflecting a beam of light.

In front of the plate *P*, another brass plate *E* is fastened, in the center of which is a small hole through which a beam of light enters to and leaves from the mirror. These two brass plates are connected together electrically by a flexible metal filament for one terminal of the instrument. The other terminal of the instrument is a small plate *F*, secured to the other side of the hard-rubber barrier. This barrier acts as a dielectric to prevent breakdown between the terminals.

Because of the inertia and high damping of the moving plate, it does not vibrate, as in the original instrument, but gives a steady deflection with constant voltage. It is immersed in oil to prevent corona and brush discharge and also for damping purposes. The deflection of the instrument is nearly proportional to the square of the voltage impressed between its terminals and consequently the deflection is always in the same direction.

The capacitance of this instrument between terminals is extremely small, approximately 0.0000017 microfarad or 1.7 micro-microfarads.

At times when the instrument was too sensitive for the voltages to be measured, multiplying capacitances of either 3.1 micro-microfarads or 12 micro-microfarads were used to keep the deflection within the range of the scale.

Two short samples of single-conductor cable were manufactured upon which measurements could be made —one sample with paper insulation and one sample with varnished cambric insulation. Each sample consisted of a No. 4 A. W. G. stranded copper conductor with a total wall of insulation of approximately 9/32 in. (7.1 mm.), and a lead sheath. At four different points in the walls of insulation, layers of No. 36 A. W. G. bare copper strands were spiraled the length of the sample between layers of the insulating material. Figs. 18 and 19 show the dimensions and locations of the copper strands.

Thermocouples were placed in the conductors and in the lead sheaths of both samples so that it was possible to know accurately the temperature of each.

Sixty-cycle alternating current was applied to the samples from a current transformer and voltage measurements were made with an impressed voltage between conductor and lead of 10,000 volts.

The minimum capacitance between successive layers of copper strands was 950 micro-microfarads. It is

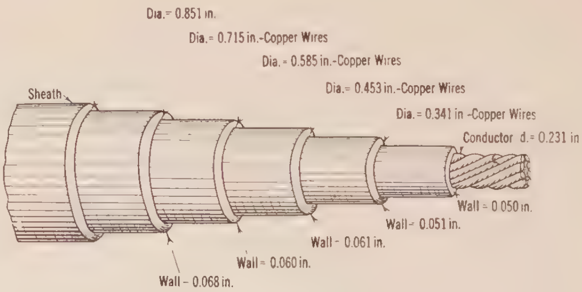

Fig. 19—Dimensions of No. 4 Stranded Cambric-insulated Stress Sample

evident that because of its small capacitance the electrostatic voltmeter already described could be used to measure voltages between layers of copper strands without disturbing the voltage distribution through the wall of insulation.

The voltage measurements were so made that one

8. Transactions of A. I. E. E., Vol. XXXV, Part 1, page 133.

side of the voltmeter was constantly at ground potential.

Tables VII and VIII show the results of 1000-cycle capacitance tests made on the samples at the various temperatures.

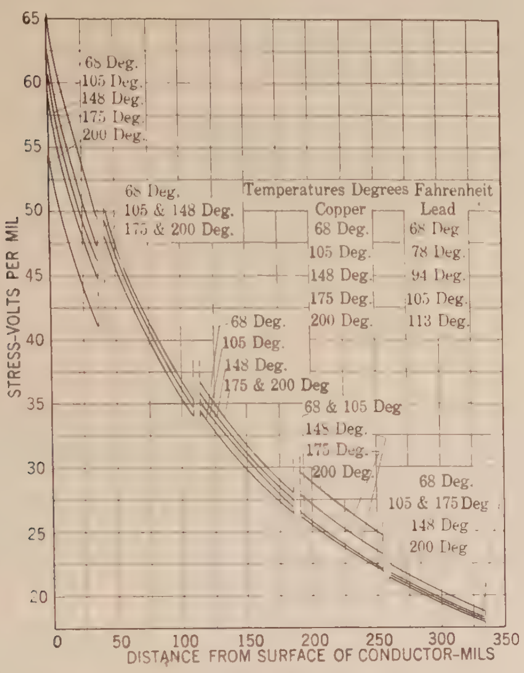

Fig. 20—Effect of Copper Temperature on Potential Gradient of Paper Cable

Four-stranded 0.295-in. wall impregnated paper
Temperature in degrees fahrenheit

The increase of capacitance for the paper cable is small, being only 11.3 per cent for the wall of insulation nearest the conductor and 6.1 per cent for the wall farthest from the conductor. The capacitance measurements indicate that any change in voltage distribution with increase of internal temperature is small, and, except in cases where the insulation is working very close to the breakdown stress of the material, the decrease of maximum stress is of very small value.

The actual voltage distribution through the wall insulation cannot be calculated from low-voltage capacitance measurements because the capacitance of insulating material under high-voltage stress is somewhat higher than when the stress is practically zero as has already been pointed out.

Table IX and Table X show the voltage as measured between the grounded lead sheath, and the layers of copper strands.

Tables XI and XII show the voltages between successive layers of copper strands as calculated from the data in Tables IX and X.

Figs. 20 and 21 show the potential gradient curves plotted from the data in Tables XI and XII. The curve for each copper temperature is indicated and the corresponding lead temperature is shown in the accompanying chart.

The first tests were made after the samples had been kept in the laboratory for several days so that the total wall of insulation was at room temperature. The potential gradient curves for these temperatures are smooth and continuous, the maximum stress on each layer being the same as the minimum stress on the preceding layer. This might be considered a good check on the accuracy of the apparatus used.

While both the paper and varnished cables show a decrease of maximum stress with an increase of internal temperature, there is quite a marked difference in the two sets of curves.

The most marked change of stresses in the cambric cable is between the second and third layers, while the change for the paper cable comes much nearer the conductor, between the first and second layers. There is no apparent reason for this, except possibly a difference in thermal resistivity. Some difference between the results obtained with the paper cable and those obtained with the cambric cable might be expected. This is due to a change in the physical state of the impregnating compound used in the paper cable with a rise of temperature, while the physical state of the insulating material of the cambric cable remains practically constant.

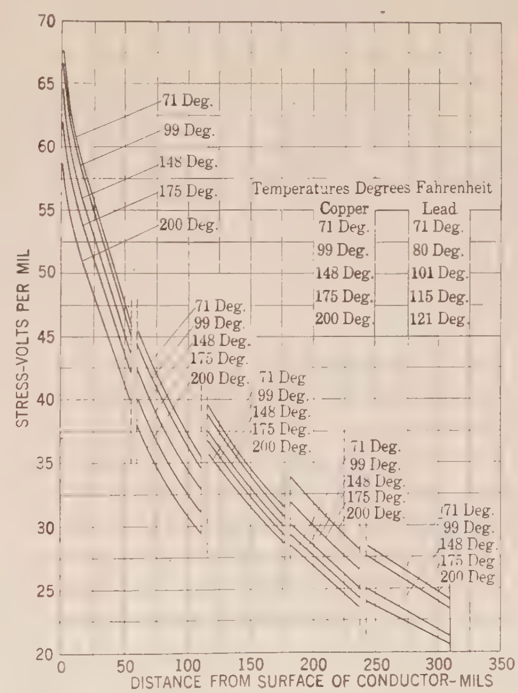

Fig. 21—Effect of Copper Temperature on Potential Gradient of Cambric Cable

Four-stranded 0.270-in. wall varnished cambric
Temperature in degrees fahrenheit

The maximum voltage that can be safely impressed across a wall of insulation depends upon the dielectric strength of the insulating material. The factor of safety for an operating cable is the ratio of the dielectric strength of the insulating material to the maximum stress produced by the working voltage. Either an

increase in the dielectric strength or decrease in the maximum stress results in an increase of the factor of safety.

$$\text{Factor of Safety} = \frac{\text{Dielectric Strength}}{\text{Maximum Stress}}$$

If both the dielectric strength and the maximum stress of a cable be changed the effect on the factor of safety would be the ratio of change of dielectric strength to the change of maximum stress.

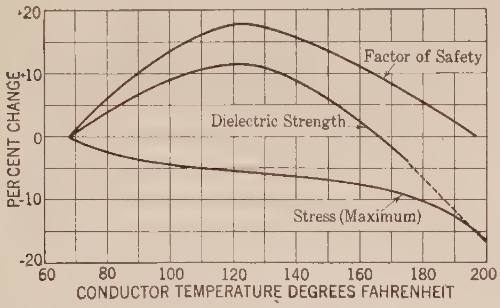

FIG. 22—EFFECT OF DIELECTRIC STRENGTH AND DIELECTRIC STRESS ON THE FACTOR OF SAFETY OF PAPER CABLES

Per cent change in maximum stress vs. conductor temperature
Per cent change in dielectric strength vs. temperature
Per cent change in factor of safety vs. conductor temperature
Paper-insulated cable

Fig. 22 shows the per cent change in maximum stress for the paper cables as the temperature of the cable is increased. There is also shown the per cent changes in dielectric strength with temperature change for impregnated paper insulation as determined from many breakdown tests. The ratio of the changes in dielectric strength to the changes in dielectric stress is plotted to show the changes in the factor of safety.

Fig. 23 shows the dielectric strength, the maximum stress and the factor of safety curves for the cambric cable.

It is interesting to note that the factor of safety for these paper cables is 4 per cent higher at 185 degrees fahrenheit, the A. I. E. E. temperature limit, than it was at normal temperature at 68 degrees fahrenheit.

In studying and discussing the curves and data of this paper, it should be borne in mind that these results are only an indication of what happens in the dielectric because of the internal heat generated at the conductor. The quantitative values would be affected considerably by the conditions under which the cable is working, probably mostly by the relative copper and lead temperatures.

CONCLUSIONS

The experimental evidence given indicates that:

1. For values of D/d equal to or less than 2.72, the potential gradient within a wall of insulation follows the simple logarithmic formula. The maximum stress may be calculated by the formula

$$S = \frac{0.868\, V}{d \log_{10} \dfrac{D}{d}}$$

2. For values of D/d greater than 2.72, the layers of insulation adjacent to the conductor can be subjected to stresses far in excess of those which the insulation can normally withstand and yet complete rupture does not occur.

The following modified formula can be safely used to determine the breakdown stress for small conductors with a heavy wall of insulation

$$S = \frac{0.868\, V}{d_c \log_{10} \dfrac{D}{d_c}},$$

where $d_c = \dfrac{D}{2.72}$

3. The stress across the inner layers of a cable having a large ratio D/d is not relieved to any considerable extent by a change of capacitance produced by the stress.

4. Breakdown tests of a special cable with an intermediate sheath at the point $D/2.72$ indicate that the insulation within the diameter $D/2.72$ adds nothing to the dielectric strength of the cable.

5. For values of D/d greater than 2.72, our data indicate that for any given dielectric, a straight-line law exists between the gradient at the conductor surface at breakdown and the ratio D/d.

6. Results of the large number of breakdown tests which are given show that in calculating the maximum stress in three-conductor cables the wall of insulation should be assumed equal to the total insulation between conductors rather than between conductors and the center of the cable, the delta voltage being used in the computation.

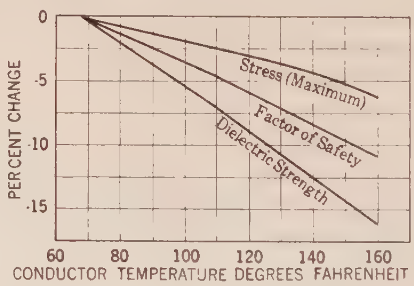

FIG. 23—EFFECT OF DIELECTRIC STRENGTH AND DIELECTRIC STRESS ON THE FACTOR OF SAFETY OF CAMBRIC CABLES

Per cent change in maximum stress vs. conductor temperature
Per cent change in dielectric strength vs. temperature
Per cent change in factor of safety vs. conductor temperature
Varnished cambric-insulated cable

7. Heat generated at the conductor of an insulated cable causes only a small change of capacitance of the insulation nearest the conductor and consequently only a slight "grading" of the cable. No dependence should be put upon the difference of temperature between conductor and outside of the cable to automatically grade the insulation.

Philadelphia-Pittsburgh Section of The New York-Chicago Cable

BY JAMES J. PILLIOD

Member, A. I. E. E.

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Engineering and construction features involved in a complete telephone cable system over 300 miles in length and connecting Philadelphia and Pittsburgh, Pa. are described in the following paper. This cable is designed to operate as an extension of the Boston-Washington underground cable system with which it connects at Philadelphia. It is also designed for operation in connection with the Pittsburgh-Chicago cable now under construction, and other cable projects included in a comprehensive fundamental plan.

Beginning with the fundamental factor of public requirements for communication service between cities separated by various distances, there are next considered the methods available to provide this service. Small-gage, quadded, aerial cable, which was decided upon for use in this section after careful economic studies, is described in a general way and the important advantages of the application of loading and telephone repeaters are outlined. The use, in connection with this cable, of the recently developed metallic telegraph system for cables is referred to and some facts are given regarding power plants, test boards and buildings. A few of the many possible combinations of cable and equipment facilities into complete telephone circuits, which will furnish the service required as economically as now possible, are illustrated.

The necessity of complete coordination of the many factors involved in a project of this kind is emphasized.

Introduction

The placing in service in the latter part of 1921 of the final section of a continuous telephone cable over 300 miles in length between Philadelphia and Pittsburgh marked a new point of achievement in the steady development and construction of facilities designed to render to the public the best possible long-distance telephone service. Furthermore, this cable forms an important part of a comprehensive plan of long-distance already completed, forms the groundwork for large expenditures in the future, it is usual to inquire first into the underlying reasons for carrying out the project and then into the methods adopted. In the following discussion an endeavor will therefore be made to furnish some information on these two items in their relation to the Philadelphia-Pittsburgh cable, although, as will be obvious, the many different points can be covered in only the most general way in the space available.

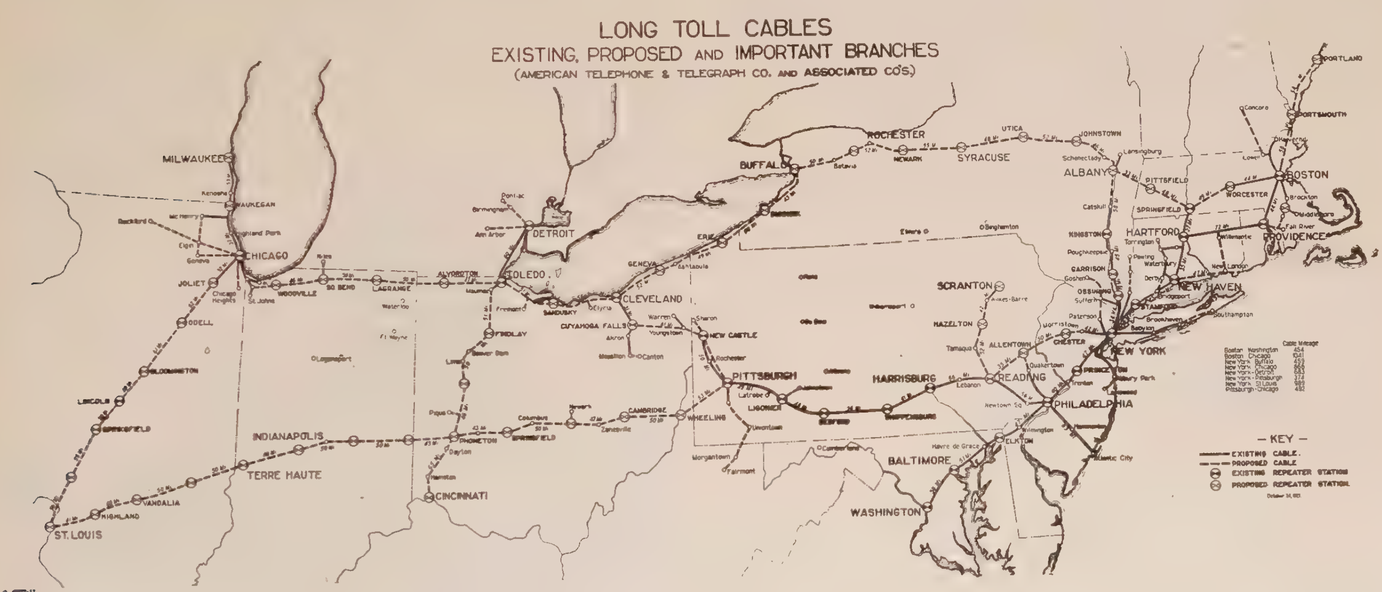

Fig. 1—Routes of Existing and Proposed Long Telephone Cables

cable construction throughout that section of the United States lying in general east of the Mississippi River and north of the Ohio and Potomac Rivers.

In the discussion of a project of this kind which involves many new practises and the expenditure of several millions of dollars and which, with related work

However, before going ahead with the discussion, I would like to point out that this project is not unlike many others in that, as a whole and in the component parts, there have been required, first, the careful consideration and decisions of the executives, then the underlying work of many scientists, inventors and engineers, then the skilled work of the manufacturers and construction forces, and finally the maintenance and operation by trained people who are responsible for the

Presented at a meeting of the Philadelphia Section of the A. I. E. E., January 9, 1922, and at the Annual Convention of the A. I. E. E., Niagara Falls, Ont., June 26-30, 1922.

continuous service so vitally necessary to the industrial and social structure of the country. The point to be emphasized here is that the coordination of all of these factors and the close cooperation of all of the many hundreds of people concerned are the important things.

General Cable Plans and Routes

Fig. 1 is an outline map of a section of the United States and shows the routes of existing and proposed long telephone cables of the Bell system. It will be noted that the present and proposed routes follow in a general way the routes of trunk-line railroads. This general section contains more than 50 per cent of the entire population of the United States but less than 15 per cent of the area, and the industrial and telephone development is, of course, very great. Furthermore, the nearby surrounding states, supplying as they do

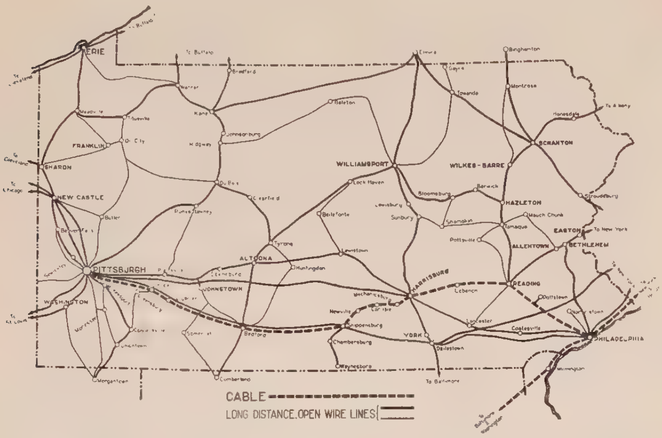

Fig. 2—Outline Map of Pennsylvania, Showing Aerial Line and Cable Routes

large quantities of food products and raw materials, are commercially related to this section in a very peculiar way and this fact greatly influences the long-distance telephone development along the particular cable routes indicated. The routes through the State of Pennsylvania and the offices at Philadelphia and Pittsburgh, which are the terminals of the cable that is more particularly the subject of this discussion, occupy strategic positions in this system.

Circuits of the American Telephone and Telegraph Company and the Bell Telephone Company of Pennsylvania are carried over these routes and this cable was jointly planned and installed by these companies.

Fig. 2 is an outline map of the State of Pennsylvania and shows the situation in this section a little more in detail. On this map are shown some of the larger cities and routes of the longer and more important toll and long-distance telephone lines. As indicated, these lines are mainly of the familiar aerial wire type which has been generally used in the past for this purpose and which is today the most efficient and economical type of construction for many cases. In the general section between Philadelphia and Pittsburgh the requirements for circuits are very heavy and in addition, as is well-known, the topography of the country is such that the through routes which can economically be used for pole lines are limited. At present, these few

Fig. 3—Damage to Section of New York-Boston Main Line Near Worcester, Mass.
Storm of November 28, 1921.

routes are fully occupied by the pole lines of the various utilities and included in these lines are three fully loaded telephone trunk lines. Another item of importance in the consideration of aerial wire construction is the very severe damage frequently experienced in many sections of the country on heavy aerial wire lines from ice and wind storms. Even lines built

Fig. 4—Section of New York-Boston Main Line Showing Wires Heavily Loaded With Ice
November 28, 1921.

with exceptional strength fail in these storms and the interruptions to service are serious matters to the users as well as to the telephone companies. The restoration costs under the conditions that naturally exist at such times are abnormally high.

Figs. 3 and 4 show the effects at one point of the ice and wind storm in New England on November 28, 1921, and are proof that this problem is real. This particular spot is near Worcester, Mass., and the line is a section of one of the principal aerial wire routes between New York and Boston. In this storm, many thousands of poles were broken and even where a few poles remained standing due to specially strong construction, the load of ice combined with the wind

Fig. 5—General View of Pole Line Carrying Aerial Cable

was too great for the wires to withstand. There is therefore a practical limit to the number of wires that can be safely and economically carried on a pole line.

Where the practicable routes for pole lines are limited, where the existing pole lines are fully loaded, and where estimated future circuit requirements are of considerable magnitude, it is obvious that different methods of providing facilities, if available, must sooner or later be given serious consideration. The conditions between Philadelphia and Pittsburgh and in general along all of the cable routes shown on Fig. 1 are now, or are expected within a few years to be, such as to make the use of some type of construction other than aerial wire desirable for most of the circuits.

After careful studies of the circuit requirements for future periods and of the methods available for providing long-distance telephone facilities, which in general are aerial wire and cable, it has been decided that for relief in these sections the cable method will give the best and most economical results. Long underground cables, as is well-known, have been in operation for many years between Boston, New York, Philadelphia, Baltimore and Washington, Chicago and Milwaukee and in other sections. However, the type of cable and associated apparatus which is now being used in the development of the more comprehensive plan is quite different from that originally used between Boston and Washington and in the other sections, particularly in the use of copper conductors of a smaller gage combined with improved loading coils, the vacuum tube telephone repeater and other methods and apparatus which are the result of recent developments. Lead-covered aerial cable supported on wooden pole lines is to be used in general on all of the routes except in the two sections just mentioned and through cities or where special conditions exist for short distances. The possibility of now using conductors of No. 16 and No. 19 A. W. G. instead of conductors up to No. 10 A. W. G. as in the older cables, has contributed to make aerial construction rather than underground conduit the more economical in many sections, as one cable will provide for a much greater number of circuits and consequently fewer cables will be required.

Line Construction

The general type of aerial construction which was used for over 250 miles of the total distance of 302 miles from Philadelphia to Pittsburgh may be seen from Figs. 5 and 6 which illustrate the poles, steel suspension strand, metal supporting rings and the cable. The poles are 25-foot untreated chestnut spaced 100 feet apart and designed to carry additional cables in the future. While the poles are new and carry only one cable they have a factor of safety of about 9 under the most severe storm conditions expected, but this will of course be reduced as other cables are placed and will gradually be decreased on account of decay at the ground line until it becomes necessary to start replacing the poles. Many of these poles were grown near the locations where they now stand. In other sections, it is planned to use butt-treated chestnut or cedar poles, or creosoted pine poles where these prove to be the more economical.

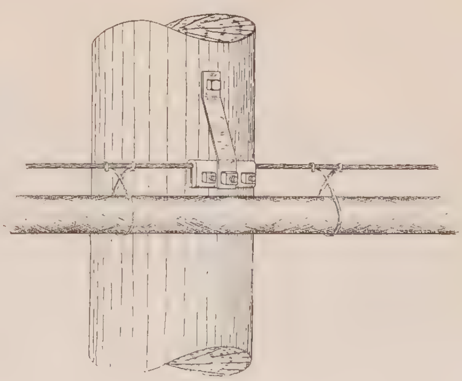

Fig. 6—Method of Supporting Aerial Cable and Messenger

The galvanized steel suspension strand has a breaking strength of about 16,000 pounds and the actual tension under normal conditions is about 7000 pounds. In placing the strand, it is necessary to pull it to just the right tension in order that when the cable is hung it will have the proper sag. The correct tension is readily determined by what is known as the "oscillation" method. The metal rings are spaced 16 inches apart and the cable weighs about 7½ pounds per foot.

The size and make-up of the cable vary somewhat

with the number of circuits of the various types that are to be provided in the different sections, but in general it is full size, that is, its over-all diameter is 2⅝ in. which is about the maximum size of telephone cable. The sheath is of lead-antimony alloy, one-eighth of an inch thick, and under normal conditions it is, of course, air-tight to keep moisture from entering. The cable for the aerial section was received from the factory in 500-foot lengths, this being largely determined by the arrangement necessary to permit the proper installation tests.

Fig. 7—Cable Line on Seven-Mile Stretch of Lincoln Highway
Aerial wire line to be dismantled later.

Fig. 8—Cable Line Across Valley at Grand View

Route

We might next consider the route selected and for this purpose Fig. 2 will again be helpful. It will be noted that starting at Philadelphia, the cable is routed to Reading touching Pottstown, Phoenixville and other points. From Reading to Harrisburg the cable follows closely the William Penn Highway, although in sections it was necessary to obtain private right-of-way or to use longer routes removed from this highway on account of the lines of various kinds already in operation there. It is very desirable for economic reasons to keep the length of these cables as short as possible and in some cases this is absolutely necessary to obtain proper operating conditions. However, the most direct routes cannot always be used, for many obvious reasons, and this problem required careful consideration in all sections of the cable.

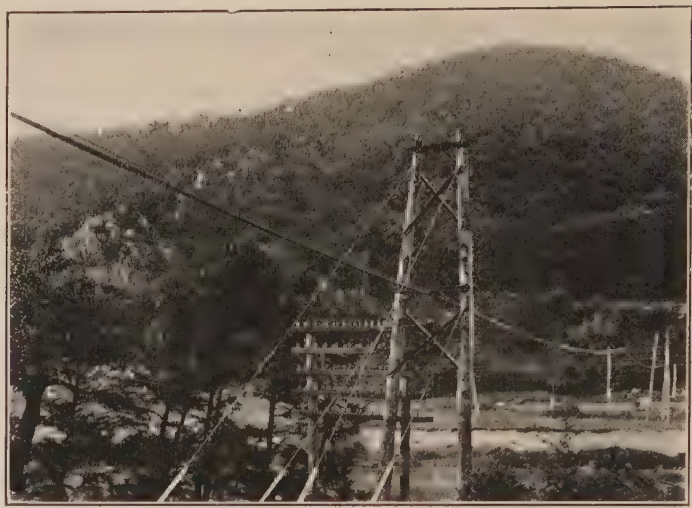

Fig. 9—Cable Crossing at Juniata River

Fig. 10—Cable Line on Steep Slopes

Between Harrisburg and Pittsburgh the Allegheny Mountains had to be crossed and for this crossing only two general routes were found practicable, the first following an existing pole line which is the New York—Chicago telephone line through Lewiston, Altoona, etc., and which we may call the northern

route, and second a southern route through Shippensburg, Bedford and Ligonier for the most part along the Philadelphia-Chicago line and also the Lincoln Highway. A middle route which is now used for the Harrisburg-Pittsburgh line was not seriously considered as the country was too rough for economical construction and maintenance and no important advantages were to be obtained. After careful surveys and cost studies, taking into account all existing and anticipated conditions, such as circuit requirements and towns to be reached, length of practicable routes, maintenance conditions, freedom from probable physical and electrical interference, etc., it was decided to build on the southern route.

This route, while of nearly the same length as the northern one and offering some important advantages, was not free from difficulties as it crosses the Allegheny Mountains within a few miles of the highest point. Fig. 7 shows the cable line on what is known as the seven-mile stretch of the Lincoln Highway east of

Fig. 11—Narrow-Gage Mountain Railroad and Flat Car

Ligonier, and here the going was fairly good. The Philadelphia-Chicago aerial wire line is also shown and two of the crossarms carrying 10 wires each are to be removed in the near future and the circuits operated in the cable. It is planned to remove the remaining two crossarms later on. Fig. 8 shows the cable across a valley and is taken from the point on the Lincoln Highway called Grand View. Fig. 9 shows the crossing of the Juniata River east of Bedford where special construction was used. Fig. 10 shows just one example of the conditions encountered in crossing the many mountains and a photograph does not do the scenery or the construction difficulties justice. On account of the steep slopes, clamps are used at many points to fasten the cable to the strand.

Narrow-gage timber railroads were used in the mountains where possible to get material to the job and Fig. 11 shows one of the regular flat cars adapted for our purpose. Fig. 12 shows two 5-ton tractors in action on top of one of the mountains. As many sections of the country are very rough and highways several miles distant it seemed that no other method of transporting the cable reels, which weigh nearly 5000 pounds, could possibly be used, and certainly no

Fig. 12—Tractors Placing Cable Reels in Rough Country

other means would have been as satisfactory. Even with these methods the cable reels could not always be delivered where desired and in some cases it was necessary to pull the sections of cable through the rings for a distance of nearly a mile to get them in place.

Fig. 13—Piece of Cable with Sheath Partly Removed

Cable Make-Up

As stated before, the make-up of the cable varies somewhat with the circuit requirements in the different sections but the wires and arrangement in a typical section of cable are roughly illustrated in Fig. 13.

The cable is of quadded construction, that is, the wires are first wrapped with dry paper for insulation and twisted into pairs and then two pairs are twisted into what is called a quad. These quads are arranged in concentric layers as shown and great care and skill are required in the design and manufacture or there is

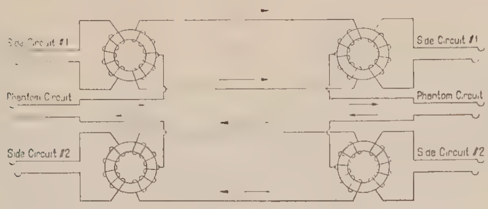

Fig. 14—General Phantom Circuit Arrangement
Four wires providing three circuits.

certain to be serious cross-talk between the several hundred circuits when used for long-distance service. Even after the application of the best present manufacturing methods, tests are made on all circuits at three points in each loading section of 6000 feet while the cable is being spliced. These tests are made in order to determine the best possible arrangement of conductors for still further reducing cross-talk between circuits, and the splicing is done accordingly.

There are 19 quads of No. 16 A. W. G. and 120 quads of No. 19 A. W. G. pure copper conductors in one of the principal sections, and the arrangement of the four wires in each quad is such that two physical circuits and one phantom circuit are made available. The method of obtaining three telephone circuits from two pairs of wires is old and extensively used. It is illustrated in Fig. 14. The method results in a 50 per cent increase in the number of available circuits and its application to this project is therefore of very great economic importance. Now the total of 139 quads multiplied by 3 gives 417 circuits or as many as could be carried on about 14 heavily loaded pole lines if aerial wire were used, but as will be described later, we will have to use two of these circuits to make one telephone

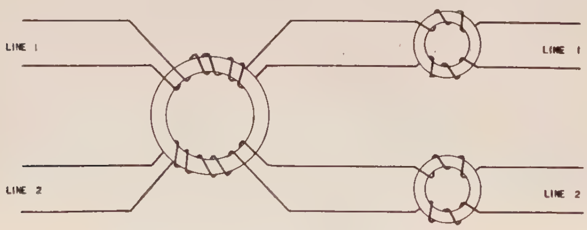

Fig. 15—Loading Coils Connected to a Group of Four Wires and Arranged for Phantom Operation

circuit in some cases where the distances are comparatively great, so it is expected that only about 300 telephone circuits will be obtained for regular service. This is as many as could be carried on 10 heavily loaded pole lines if aerial wire were used. It is now thought that in some sections this number of circuits will take care of future demands for about 10 years after allowing for the dismantling of some existing aerial wire.

As these cables can be obtained in any size desired up to the maximum, the period for which they should be engineered can be determined from studies of circuit requirements and costs. These studies are of very great importance and the cost considerations include of course annual costs of the various plans over proper periods as well as first costs.

Loading

Loading coils are now connected to many of the circuits and all of the circuits in this cable are intended to be equipped with coils located at 6000-foot intervals. The theory and practise of loading are described in papers previously presented before the Institute[1] and

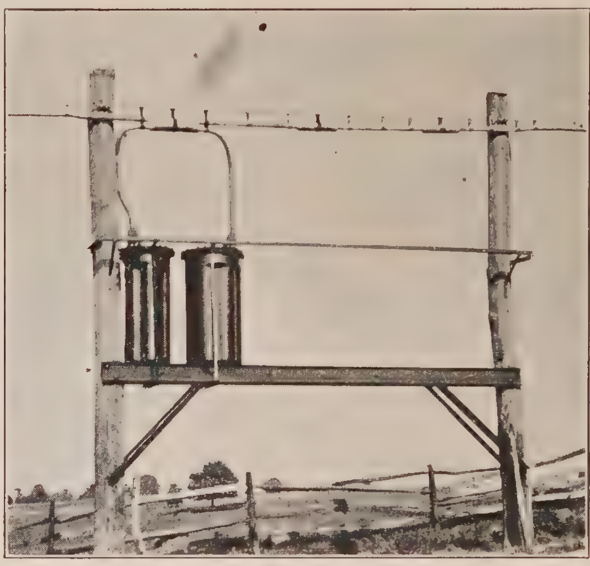

Fig. 16—Loading Fixture

for our purpose it will be sufficient to state that these loading coils very materially reduce the attenuation losses and improve the quality of transmission as compared to cable circuits not so equipped. The improvement in so far as the attenuation losses are concerned, varies with the type of circuit and loading coils, but with one of the No. 19 A. W. G. circuits in this cable loaded with coils having an inductance of 0.175 henry located at 6000-ft intervals, the losses are only about one-third as great as in a similar circuit without the coils. The connections and arrangements of the coils are shown in Fig. 15 and it will be noted that coils have been connected to both the physical and phantom circuits. The arrangement is such that there is no appreciable interference between circuits due to magnetic action in the iron cores of the different coils or to the necessarily close electrical relation in the windings.

1. Papers by M. I. Pupin, Transactions of A. I. E. E., XVII, May 1900 and XV, March 1899.
Paper by Bancroft Gherardi, Transactions of A. I. E. E., XXX, June 1911.

The loading coils are potted and sealed in iron pots, two of which are shown in Fig. 16, and in the country these are mounted on pole fixtures. Each pot contains 36 groups of 3 coils each. The pots are nearly 30 inches in diameter at the flange, 52 inches high and weigh

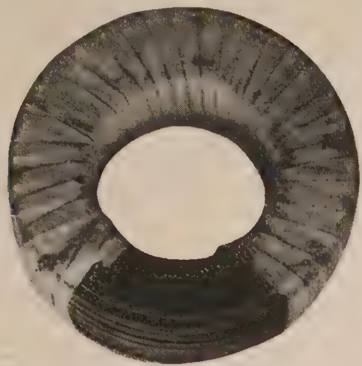

FIG. 17—LOADING COIL CORE

about 2700 pounds. The pots can be obtained in different sizes depending upon the number of coils which it is desired to install at one time. When the cable was installed, extra lead sleeves were placed at the loading points and a little slack left in the wire to facilitate the connection of four additional loading pots to the cable at some later date when the circuits are needed. The loading points must be uniformly spaced in order to obtain the proper impedance characteristics in the circuits as will be referred to later. Fig. 17 shows the iron core of a loading coil, and Fig. 18 shows this core wound with insulated wire and then wrapped with cloth and the terminals brought out nearly ready for potting.

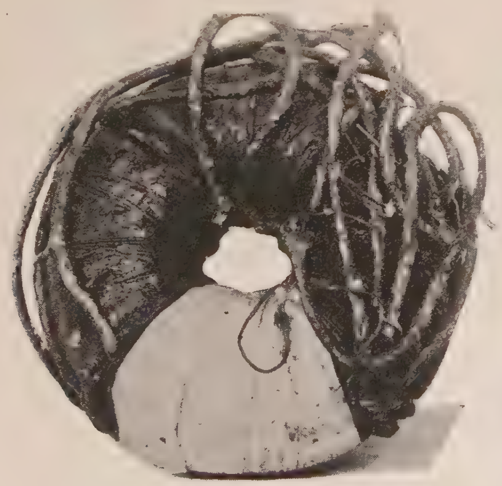

FIG 18—LOADING COIL WITH WINDING COMPLETED

Fig. 19 shows several coils arranged on one of the spindles which will be placed in the iron pot also shown. This particular pot will hold 7 spindles and when they are in place, the pot will be filled with compound and thoroughly sealed.

TELEPHONE REPEATERS

Even with the improvement in the quality of transmission and reduced attenuation losses effected by the use of loading coils, loaded cable circuits alone of No. 16 and No. 19 A. W. G. could be satisfactorily operated for distances less than 100 and 60 miles, respectively, and this is far short of our requirements in this case. In fact, we wish to operate some telephone circuits on these conductors and through this cable and future cables up to at least 1000 miles in length. This can be accomplished by the use of telephone repeaters connected to the loaded conductors.

Telephone repeaters have been developed to a high state of perfection and are completely described in a paper presented by Messrs. Bancroft Gherardi and Frank B. Jewett at a joint meeting of the A. I. E. E. and the Institute of Radio Engineers in New York,

FIG. 19—LOADING COILS ON SPINDLE, IRON LOADING COIL CASE AND SPINDLE CABLES

October 1, 1919. Briefly, the purpose of a telephone repeater is to receive small telephone currents, amplify them and send them on, preserving all the while the original wave shape. Therefore, if one or more telephone repeaters are properly inserted in circuits adapted to their use, the range of satisfactory transmission can be greatly extended. As many hundreds of vacuum-tube repeaters are in operation on the Philadelphia-Pittsburgh cable and connected cables, and as a great many more are planned for future installation, we will briefly consider the elementary features of some of the types of repeaters used.

Fig. 20 shows the structure of the vacuum tube which is an essential element of this type of repeater. It is a small glass bulb with a vacuum that is as good as is practicable to obtain. In the tube is a filament which is heated to incandescence during operation,

and a grid and plate. The circuits directly associated with the tube are shown in more detail in Fig. 21, and this would constitute a device for amplifying currents from one direction. As is well understood, any change in the potential impressed on the grid causes a change in the current flowing in the plate-filament

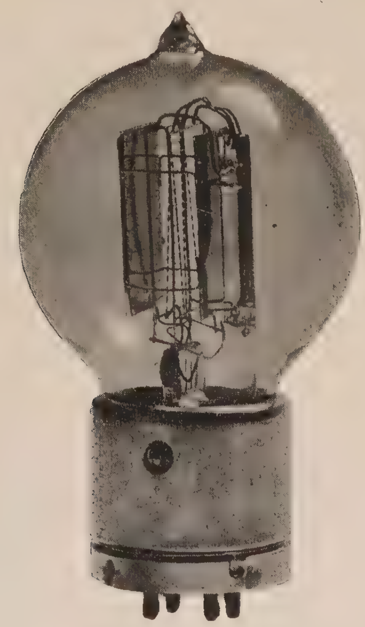

Fig. 20—Vacuum Tube

circuit. To obtain complete two-way repeater action two of these amplifier arrangements are combined with the circuits shown in Fig. 22.

It will be noted that the line circuit from one direction, for instance, the one designated "line west," is connected through a three-winding transformer to a balancing network which is so made up as to balance

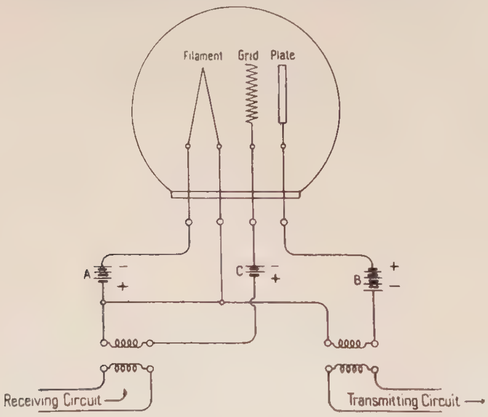

Fig. 21—Vacuum-Tube Repeater Element

the line as nearly as possible at telephone frequencies. This balance is essential to proper repeater operation. The circuit arrangement is such that part of the incoming energy is diverted to that part of the circuit containing the input coil directly associated with this three-winding transformer. By the action of the vacuum-tube arrangement amplified energy is transmitted to the line east. That part of the original incoming energy from the line west that goes through the balancing network or the output coil is not, of course, transmitted along into the line east. The operation in the casé of currents incoming from the line east is similar and it will be noted that the complete repeater circuit is made up of two symmetrical parts. This circuit arrangement constitutes what is known

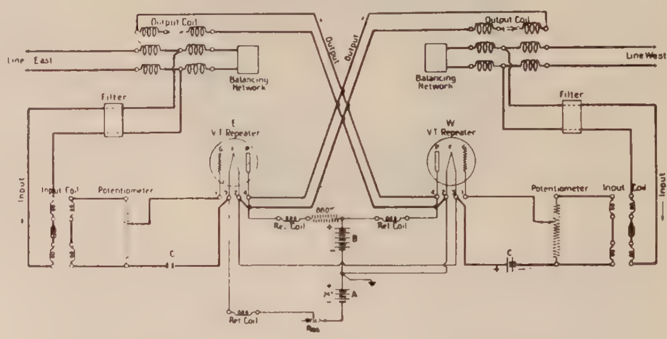

Fig. 22—Two-Way Vacuum-Tube Repeater Circuit

as a two-wire repeater and the apparatus is, of course, all closely associated in the same office.

Several of these repeaters may be inserted in tandem at appropriate points in a circuit, but there is a limit to the length of circuit that can be satisfactorily operated with this arrangement, this length depending upon the type of the facilities used. When longer circuits are required, a four-wire arrangement is used, as shown in Fig. 23. It will be noted that in this arrangement the three-winding transformers are not located in the same office but may be in offices several hundred miles apart. At each of the intermediate stations a vacuum-tube amplifier arranged for amplification in one direction only is connected to each of

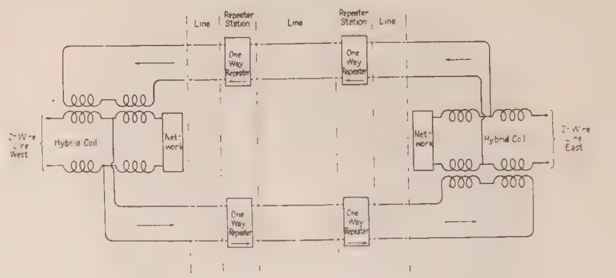

Fig. 23—Four-Wire Circuit

Equipped with telephone repeaters and arranged for connection to two-wire circuits at the terminals.

the two branches of the circuit. Two circuits are, of course, required between the terminals and these may be either physical or phantom circuits.

An advantage of this arrangement is that balancing networks are not required at each repeater station and the general matter of balance and consequently good repeater operation in the circuit as a whole is greatly simplified. This arrangement can, therefore, be satis-

factorily used for long circuits where two-wire operation might be impracticable, and examples would be such circuits as New York-Pittsburgh or New York-Chicago.

Fig. 24—Group of Repeaters at Reading, Pa.

Both of these types of circuits may be operated on No. 19 A. W. G. four-wire facilities which may be either physical or phantom circuits.

Fig. 24 shows a group of repeaters installed in the office at Reading, Pa., and Fig. 25 shows one of the four-wire repeater units in somewhat greater detail.

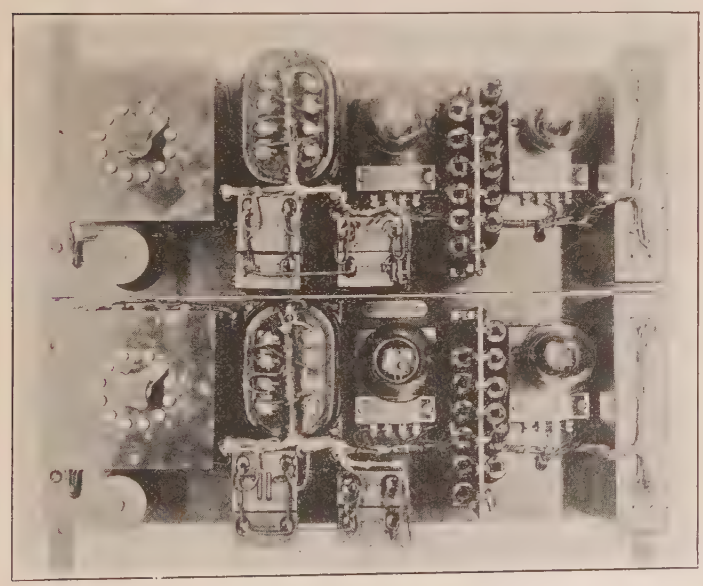

Fig. 25—Assembly of Four-Wire Repeater Apparatus

Line Impedance

In order that networks may be used to balance the lines for repeater operation, it is necessary as a practical proposition that the impedance characteristics of the lines be fairly uniform over the range of telephone frequencies. The solid line in Fig. 26 shows the resistance component of the impedance of a No. 19 loaded cable circuit with all loading coils in place. The solid line in Fig. 27 shows the resistance component found in impedance measurements on the same circuit with one coil omitted at the thirteenth loading point from the end at which the tests were made. It will be noted that in the latter case the characteristics of the circuits vary greatly with frequency. It would therefore be very difficult as a practical proposition to build up a network that would balance lines in this condition, and such variations in the electrical characteristics of a circuit impair the quality of telephone transmission, as the currents of different frequencies are differently affected. The necessity for careful maintenance work in promptly replacing loading coils which may become defective or preventing other irregularities from creeping into the plant will therefore be clear.

Transmission Regulation

The resistance of small-gage cable conductors is one of the important factors that determine the transmission losses of a circuit. The resistance of a No. 19 A. W. G. pair is about 88 ohms per mile so that in a long

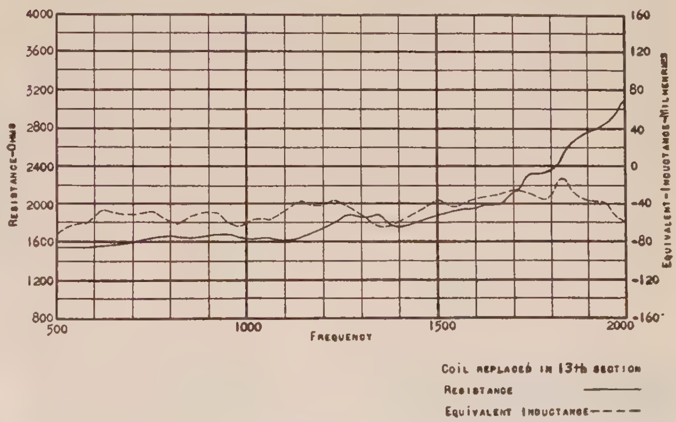

Fig. 26—Line Characteristics—A Cable Circuit in Normal Condition

circuit this factor of line resistance reaches considerable proportions. Now as most of the cable is aerial, the resistance of the conductors is of course affected by changes in temperature both daily and seasonal and the transmission losses vary accordingly. These changes in transmission values are of such magnitude that automatic transmission regulators are being provided for certain groups of longer circuits. All changes in the transmission equivalents of the circuits from whatever causes must be carefully watched and necessary adjustments made or the service will be seriously affected.

Telegraph

In the section between Philadelphia and Pittsburgh practically all of the existing long aerial wire circuits are composited, that is, they are arranged for simultaneous telephone and telegraph operation. The telegraph circuits thus obtained are generally used in furnishing what is sometimes called "leased wire" service. The ground return system providing either full duplex or single-line operation is used and the

line currents average about 75 milliamperes. This grounded telegraph system cannot be used where simultaneous telephone and telegraph service is desired on loaded cable circuits of the length involved in this

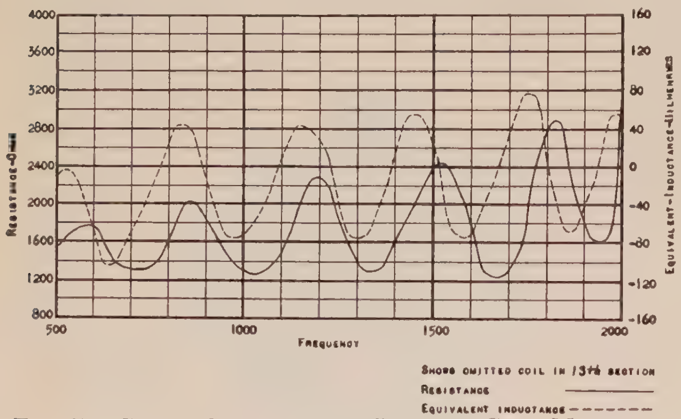

Fig. 27—Cable Circuit with Loading Coil Missing at Thirteenth Loading Point from Terminal

cable, and as a part of the work of carrying out the comprehensive toll cable plans of the Bell system, a new telegraph system had to be developed. It was found preferable to use a metallic return circuit and to limit the line current to a value between 3 and 5 milliamperes in order to prevent serious interference to the telephone circuits due to the "flutter effect,"[2] Morse thump, and mutual interference between telegraph circuits. Morse thump results when the composite sets, that is, the apparatus used for separating the telephone and telegraph currents, do not completely prevent the latter from entering the telephone circuit, thus causing interference. The telegraph repeaters are located at about 100-mile intervals on the No. 19

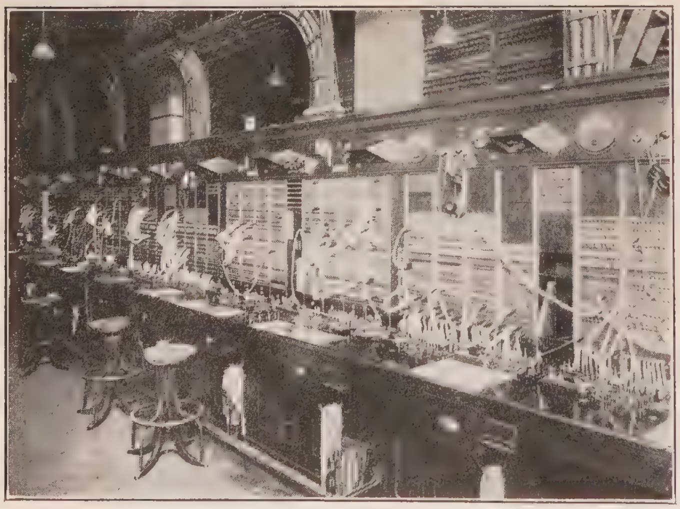

Fig. 28—Test Boards

circuits and at somewhat less frequent intervals on No. 16 circuits. The telegraph apparatus is of course located in the same buildings that are used to house the telephone repeaters, and on the Philadelphia-Pittsburgh cable telegraph repeaters will be located initially at Philadelphia, Harrisburg, Bedford and Pittsburgh.

Test Boards

All of the conductors in the cables are carried into stations located at about 50-mile intervals and apparatus is provided in these stations for making regular tests to ascertain the condition of the cable and to locate trouble quickly. At these offices the different kinds of operating apparatus are also connected to the cable conductors; examples of this apparatus are phantom repeating coils, composite sets to permit simultaneous telephone and telegraph operation, telegraph repeaters, telephone repeaters and associated balancing equipment, signaling apparatus, and where required, the switchboards necessary for making the telephone connnections involved in furnishing service.

Fig. 29—Test and Repeater Station at Ligonier, Pa.

It is necessary that this apparatus which is installed in large quantities be systematically arranged and facilities provided for making quick changes in the circuit arrangement. The circuits are wired through jacks installed in groups in test boards for this purpose and to facilitate testing. One of these boards is illustrated in Fig. 28. This particular board is located in one of the larger offices. The test boards in one of the repeater stations such as Bedford, would consist of a smaller number of positions. A position is three feet in length. In Fig. 28 each position bears a number.

Stations and Power Plants

Telephone repeaters of either the two-wire or four-wire type are connected to the circuits at approximate intervals of either 50 or 100 miles, depending upon the type of facilities which it is economical to use in the different circuits and the kind of service for which a given circuit is intended. As mentioned above, telegraph repeaters are installed at about 100-mile intervals. At some of these points existing offices are used while in a number of cases it was necessary to erect

2. Paper by Martin and Fondiller in Journal of A. I. E. E., February, 1921.

buildings for the sole purpose of housing the repeaters, testing apparatus and other equipment associated with the cable. For example, new buildings of fire-proof construction were erected at Shippensburg, Bedford and Ligonier. Fig. 29 is a view of the building at the latter

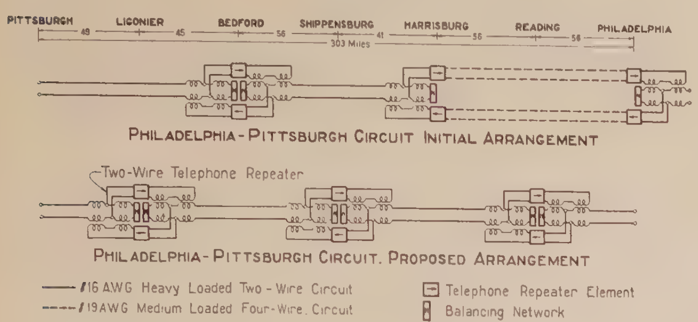

Fig. 30—Cable Circuit Arrangments

point and the other two buildings are similar to this one, the dimensions being about 50 by 80 feet. Power plants are installed in these buildings to furnish current of the proper characteristics for operating the apparatus, and storage batteries are provided to insure uninterrupted service. As an indication of the size of these plants, the 24-volt storage batteries installed for the initial load at Bedford have a capacity of 2240 ampere-hours and this provides about one day's reserve. The capacity can, of course, be increased as repeaters are added from time to time when additional circuits are needed. Storage batteries of smaller sizes supplying current at potentials of 30, 120 and 130 volts are also provided.

Examples of Circuit Arrangements

Fig. 30 shows two possible methods of building up a Philadelphia-Pittsburgh terminal circuit and Fig. 31, a method of building up a New York-Pittsburgh terminal circuit. In all three cases these telephone circuits are intended to have a transmission equivalent of about 12 miles of standard cable. Some Philadelphia-Pittsburgh terminal circuits of the first type have been in everyday operation for several months, but it is not the most economical arrangement that it is possible to obtain for general use in providing this or similar service. It will be noted that No. 19 four-wire facilities are used between Philadelphia and Harrisburg and four-wire repeaters are located at these two points. At Harrisburg the four-wire circuit is connected to a No. 16 two-wire circuit with a two-wire repeater at Bedford. This arrangement was used in order to start service through the cable with the facilities available, but it is intended later on to use the arrangement shown in example No. 2.

In example No. 2, No. 16 heavily loaded conductors are used and two-wire repeaters are located at Reading, Shippensburg and Ligonier. The total transmission equivalent of this circuit without repeaters is about 50 miles of standard cable so that in order to obtain a net equivalent of 12 miles for the circuit each of the three repeaters must give a transmission gain of nearly 13 miles of standard cable. This circuit could not of course be used for telephone purposes without repeaters.

The third example shows how it is expected to operate New York-Pittsburgh circuits intended for business between these two terminals. Four-wire No. 19 loaded cable facilities are used with four-wire telephone repeaters located at New York, Philadelphia, Harrisburg, Bedford and Pittsburgh.

Even with conductors of only two gages in the cable, it is clear that many different combinations of facilities can be built up into telephone circuits and an endeavor is always made to use the most economical arrangement that will furnish the service required over each circuit group. The examples described above are of circuits used for business between the terminals indicated and if these circuits were to be connected to others extending to points considerable distances beyond these terminals different arrangements would be required. The cable conductors used in building up these telephone circuits can be composited and telegraph circuits are thus provided for simultaneous operation with the telephone circuits.

Conclusion

In the above discussion, an effort has been made to furnish some descriptive information regarding a complete cable system recently completed and now in successful operation between Philadelphia and Pittsburgh and designed for long-distance telephone and telegraph service. In one sense this discussion may be considered a report of the present status of the toll cable plant intended to connect Atlantic Seaboard cities with Chicago and other cities, and extensions are now under construction. However, most of the general methods which it is planned to use in these extensions are not expected to differ greatly from those described.

This cable system utilizes many new developments in the communication art and some of these, which have been briefly touched on here on account of their important application, have been described in more detail in previous papers. It is expected that more information regarding other specific developments

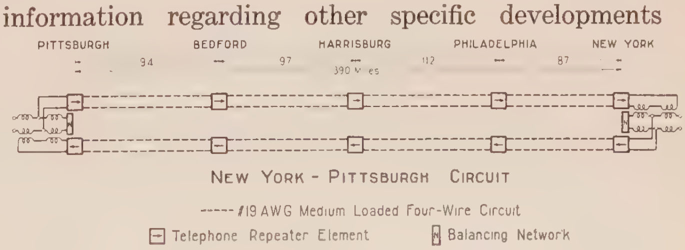

Fig. 31—Cable Circuit Arrangments

which have contributed in an important way to the successful carrying out of this project or which may be utilized later on will be furnished in future papers.

An important feature of this cable project is the fact that while many new developments and practises are utilized, the design of the system as a whole is such as to fit in economically with existing wire and cable systems and proposed extensions.

Discussion at Midwinter Convention

KEY WEST-HAVANA SUBMARINE TELEPHONE CABLE SYSTEM*

(Martin, Anderegg and Kendall), New York, February 15, 1922.

Bancroft Gherardi: The two questions that required much care and thought in the design of this cable were, first—shall the cable be continuously-loaded or coil-loaded, and, second, shall it be a single or a multi-conductor construction? There were serious questions involved in each. In the first place, as to the loading. Coil-loading is in many respects more efficient than continuous-loading, because with coil loading, you can get practically any inductance per mile that you desire, and so you can, within very considerable limits, increase the efficiency of the circuit. With continuous-loading, however, there are very sharp limitations on the possible inductance per mile that can be attained with any practical contruction. As we saw the problem at that time, and as we still see it, the coil-loading would have been chosen, for electrical reasons, but it presented most formidable mechanical difficulties. In the first place, the making of a cable of that kind, interrupted periodically by coil cases and coils, and laying it in deep water was a very formidable matter. In the next place, the maintenance of the cable would necessarily be complicated by having points of discontinuity. The attachment of the cables to the coil cases and the coil cases themselves would necessarily be elements of weakness. This weakness is not serious in a land cable, as trouble, if it occurs in a land cable, can be cleared in a few hours. On the other hand, if trouble develops in a cable of the kind in question, it may be weeks and under bad weather conditions and unfavorable location of cable ships, it might be months before the trouble could be cleared. The coils were, therefore, excluded for mechanical reasons.

The other question was the one of the single-conductor versus the multi-conductor cable, and this brought up a related question that of one cable versus several cables, that is, the question of putting all your eggs in one basket or having several baskets, each with one egg in it.

These questions, as you see, are tied right up with each other. The single-conductor cable necessarily meant grounded-circuit operation. In the case of the metallic circuit cable, the obvious method of operation would be to build probably a cable of four wires and undertake to operate two physical metallic circuits, and possibly a phantom circuit, with a more remote possibility of getting a fourth circuit, that is, a grounded phantom circuit from the combination. The data available at the time indicated there was considerable question as to whether the cable could be sufficiently well balanced to permit either of these phantoms to be used.

There you have a very nice problem, but it involves other than perhaps strictly engineering considerations although not otherwise when engineering is interpreted broadly. Should we lay one cable and use the usual methods of operation, and get two circuits, and perhaps three or four. We would get them probably somewhat more cheaply that the circuits with three separate one-wire cables, but always with the chance that some time or other the cable will fail and then the service will be completely interrupted for an indefinite period.

The choice finally was determined by that consideration—by the consideration that we could not, in a service of that kind, which should be made as far as practicable dependable—we could not afford to put all of our eggs in one basket, as we might lose the whole cable at one time. Therefore the alternative of three separate cables was chosen, although it required a great deal of study and investigation as to the general question of the grounded circuit operation of cables of that character, and their operation under the particular conditions existing between Key West and Havana. Our investigation satisfied us that we could safely count on that method of operation.

These investigations were very extensive and very carefully made. We satisfied ourselves that the cable itself, and the service from it with any degree of amplification we would wish to place on it, would be satisfactory.

William McClellan: Mr. Gherardi referred to some of the problems that might not be settled by engineering consideration. In its simplest form my question is, "What effect is long distance wireless communication going to have on long distance telephone?" At present there is a certain lack of secrecy which our customary long distance lines give in part at least.

Bancroft Gherardi: I will be glad to say a word in answer to the question which has been asked. The matter of utilizing wireless in that connection was very carefully considered at the time the cables were being considered and it has been reconsidered recently in this form—if we were to do the job again, would we do it by means of wire or wireless? In each case the answer has been the same. Most of the communication has been on business, matters—particularly last spring, and to a certain extent this fall, there were a number of very serious financial failures avoided by the use of the cables. These were matters which required prompt communication with a considerable number of different institutions, and if action was not taken in twenty-four hours there would be a financial failure, and there was a situation in Cuba in which a few failures might start things going and create a very much more serious state of affairs than the one which actually existed.

Obviously. wireless communication, certainly in the present state of the art, would have been entirely unsuited for such service.

The mere mention of such topics in the air, the broadcasting of such questions as were discussed in these communications would create the effect which it was desired to avoid. But excluding altogether the matter of secrecy, and excluding altogether the matter of interference, atmospheric or otherwise, we have thus far been unable to figure out how we could give an equally extensive and dependable service and give it as cheaply by means of radio across that distance, as we can by means of the cables.

*A. I. E. E. Journal, Vol. XLI, 1922. March, p. 184.

SUBMARINE CABLE TELEGRAPHY*

(Milnor,) New York, N. Y., February 15, 1922.

M. Sasuly (Communicated after adjournment): In regard to the theory of operation of cables as given in the paper, some qualifying remarks may be appropriate. The statement of the mathematical basis on which the character of signals can be predicted (p. 124) is likely to be misinterpreted. It implies that the mathematics of ordinary a-c. theory alone suffices for the determination of the "transient" as well as the "steady state" characteristics of cable and other circuits. This is correct only in the broad sense that the "transient" solution can be made to depend on the "steady state," or "periodic" solution because both are fundamentally of the same mathematical type, the general exponential function. But it is not to be inferred that the one solution can be derived from the other merely by the processes of ordinary a-c. mathematics. Also it must be noted that the identity in type of the two solutions is limited by certain conditions. These involve considerations of the invariability of the circuit "constants" with current and voltage, the linearity of the differential equations, and the "boundary" conditions applying in the given problem. The scope and importance of these restrictions must not be overlooked. In many practical problems they inevitably introduce considerable mathematical complexity.

*A. I. E. E. Journal, Vol. XLI, 1922, February, p. 118.

The possibility of deriving the "telegraphy" solution of the cable problem directly from the a-c. solution has been a matter of controversy among a number of cable engineers. The issue does not concern merely the question of mathematical method. It is fundamental in the very practical problem of improved signalling through ocean cables by means of high-frequency currents. (Cf. Wagner, "E. T. Z." 1910, p. 163; 1912, p. 1289. Malcolm, Theory of the Submarine Telephone and Telegraph Cable, 1917, pp. 248-251). Consequently it is appropriate to call attention to what is perhaps the essence of the theoretical aspects of the problem.

Under the restrictions referred to previously the "transient" and "periodic" terms constitute the *general* solution. This is composed of a sum of terms of the type of the *particular* solution, the latter corresponding to the "periodic" solution. This fact is seen with little difficulty in the Fourier integral solution of the cable problem, first given by Kelvin about 1854 (Math. and Phys. Papers, II, pp. 48-49), and treated by a number of subsequent writers, with particular concreteness by Heaviside (*e. g.*, Electromagnetic Theory, II, p. 125 (1895)), Poincare (Théorie de la Propagation de la Chaleur, 1895, p. 134; L'Eclairage Electrique, 40, p. 162, 1904), and Wagner ("E. T. Z.," l. c.; Mitteil, Teleg. Vers., V-VI, 1909-1912). The applicability of the Fourier integral solution to circuit networks has been shown by several writers, especially by Wagner (*Archiv. f. Electrotechnik*, 4, p. 162, 1916), Carson (TRANS. A. I. E. E., 38, p. 359, 1919), and Fry (*Phys. Rev.*, 14, p. 118, 1919); also by Pomey (*Revue Gen. de l'Elec.*, 5, p. 204, 1919). In the solution of cable and network problems by Heaviside's Expansion Theorem (l. c., p. 127), the correspondence of the "transient" and "periodic" terms to the constituents of the general solution is no longer apparent. But the correspondence has been explicitly established in the very lucid and direct analytical proof of the Expansion Theorem given by Carson (Phys. Rev., 10, p. 217, 1917).

It is true then that the general solution of ordinary circuit problems can be formally derived from the same type as the a-c. solution. But this fact must not lead to under-estimating the complexity of the process of actually constructing the solution. The use of integral equations, Bessel series, (*e. g.*, Carson, Fry, l. c.) and other advanced mathematical processes is not merely a matter of elegance. Advanced methods are unavoidable in all but very simple and certain special types of circuit problems. Moreover, certain important aspects of the solution are entirely outside the scope of ordinary a-c. methods. These relate to the properties of the *indicial impedance function* (Cf. Carson, l. c.) associated with a circuit system. The roots of this function determine the "natural modes of motion" of the system. A study of these would appear not only to facilitate the solution of given circuits, but also to admit the possibility of designing circuits of predetermined characteristics.

J. W. Milnor: The foregoing discussion indicates that the scope of the paper has been somewhat misunderstood by the writer of the preceding communication, and it may be misunderstood by others. An original method of calculating transients is developed in the Appendix, and it is clearly shown that a transient may be directly determined from a knowledge of the behavior with continued sine wave alternating currents, of the electrical circuit under investigation. The amount of labor involved in the solution is of course by no means nil, since it is necessary to know the behavior of the circuit with alternating currents throughout a range of frequencies; and to take the step from alternating-current theory to the transient solution, it is necessary to make a definite integration which must be performed either analytically, graphically or mechanically. However, the method is straightforward, and does not involve Bessel series, operational methods, or a determination of roots of a function. The results are summed up in equations (**10**), (**12**) and (**13**) of the Appendix. This general method should not be confused with the subject of "transient oscillations" or "high-frequency signaling," which has been covered by different writers.

There are certain restrictions to the method of calculating transients given in the Appendix which while ordinarily not important, should perhaps be specifically mentioned. It is assumed throughout the mathematics that the circuit parameters are invariable with current and voltage,—although it is permissible that they might change with frequency. If the method is used in the solution of a circuit (of academic interest only) which contains no resistance, misleading results will in general be obtained. This condition follows from the fact that the method of development assumes that the quantity k although large, is finite. It is possible to apply the method for solving electrical circuits containing inductance and capacity only, by taking certain precautions, although it appears inadvisable to discuss such considerations here because of their complication. There is a slight omission relative to equation (**7**) of the Appendix; it should have been stated that this equation is valid *for values of m greater than one*, when k is large.

The suggestion has been previously made at different times that there might be some direct relation between the "telegraph" solution of the cable problem and the alternating-current solution or that it might be possible to derive one from the other. As far as the author knows, however, this is the first time that a mathematical justification for such a relationship has been published.

While the use of this method for calculating general transient effects in an electric circuit involves the performance of an integration,—such an integration may usually be avoided in investigations of ocean cable lines and apparatus. This simplification is made possible by the expedient of determining once for all what *frequency characteristic* a cable circuit must have in order to transmit satisfactory signals. Examples of such frequency characteristics are shown in Fig. 12 of the paper. A certain degree of variation from these is of course possible in practise, since a certain amount of variation in the shape of received signals is permissible. The behavior of an ocean cable or of its apparatus may therefore be directly determined by investigating its behavior with alternating currents,— *i. e.*, its frequency characteristic,— throughout the range of frequency from zero to about twice the dot frequency.

PRINTING TELEGRAPH SYSTEMS APPLIED TO MESSAGE TRAFFIC HANDLING*

(REIBER). NEW YORK, N. Y., FEBRUARY, 15, 1922.

R. E. Chetwood: At the present time, in the Western Union System, we have about 185,000 miles of trunk wires, equipped with automatic, printing telegraph apparatus. If the automatic apparatus had not been used it would have required approximately 460,000 miles of wire to handle the same amount of traffic. That shows a great saving in wire plant, due to the use of automatic apparatus.

Another figure that possibly would be of interest is that today approximately 75 per cent of the trunk line traffic is handled by automatic apparatus. By automatic apparatus, I refer to apparatus of the type described in the paper and also the heavy traffic apparatus which was described in Mr. Bell's paper of two years ago.

John H. Bell: The author has not mentioned that all three systems can be operated duplex. As a result of this omission the following sentence in the first column of page 89, towards the bottom which reads: "This necessitates two motors, but with this arrangement, transmission may be carried on in opposite directions at different speeds and accurate speed adjustments are not necessary," might lead one to think that in order to secure transmission in both directions, that i-, to operate duplex, it is necessary to have two motors. Such is not the case. I think it was Mr. Reiber's intention to emphasize the fact that

*A. I. E. E. JOURNAL, Vol. XLI, 1922, February, p. 79.

a different speed in each direction is obtained by the use of two motors.

He might have claimed for printing telegraphs the advantage of greater accuracy. In the majority of the operating rooms of one of the largest telegraph companies in this country, there are large notices reading: "Accuracy First." In the final analysis, the standard of accuracy depends upon the operator, but the use of printing telegraphs enables the operator to give so much more time to the checking of the messages that the standard of accuracy is considerably higher than with the old Morse instruments. As a matter of fact, I believe that the number of undetected errors in the case of printing telegraph systems is only about thirty to forty per cent of the number of undetected errors with Morse.

Just picture a telegraph organization in a position to print at the bottom of each message blank which goes out to the public—"There is no error in this message". The use of the printing telegraphs has made it possible to proceed a long way toward that high standard.

While on the subject of accuracy, I will mention one or two slight inaccuracies in the paper. Fig. 16 shows the Western Electric printer with relay box as arranged for multiplex operation, which is different from the arrangement for the start stop system as shown in Fig. 12. Fig. 15 shows the Western Electric receiving face plate with four rings. Four ring face plates have been abandoned and now only the two rings are used.

If the printer systems described by Mr. Reiber can successfully compete with the Morse system when operated by the skilled Morse operators in America—and they do—then there should be no difficulty in having them compete with Morse operators in other parts of the world.

G. D. Robinson: What is the possibility of applying the printing telegraph to wireless communication?

A. H. Reiber: I believe there will be developments along those lines in the future. In applying automatic printing telegraph equipment to wireless communication there is a condition, that of static, which is hard to overcome. Where the human element is involved, it is possible to receive signals even though they are badly mutilated but with automatic printing telegraph equipment, unless future developments correct the difficulty, static disturbances will occasionally cause unintelligible words.

CONDENSER DISCHARGES THROUGH A GENERAL GAS CIRCUIT*

(Steinmetz), New York, N. Y., February 15, 1922

V. Karapetoff: I shall first consider the specific cases treated by the author, and then the general case, which he puts first.

The first two cases, A and B, correspondong to $E = 0$ and E = constant; they do not require any special or new method of integration of the fundamental eq. (**4**), since the troublesome term, $d\,E/d\,t$, vanishes. Hence, these cases lead to familiar decremental sinusoidal expressions. The fact that in the second case the discharge stops after a finite number of alternations is very interesting, and it follows directly from the nature of the circuit.

In the case C the shape of the current wave is assumed *a priori*, so that no integration of the fundamental equation is necessary. This case seems somewhat arbitrary, in that a physical quantity, E, instead of being taken in the beginning as a certain function of i, according to experimental facts, is deduced theoretically from an assumed law of variation of current. Of course, the shape of the current in the oscillograms (Figs. 8 to 10) shows the reasonableness of such an assumption, but the mathematical results for q and c are so complicated as to minimize the importance of this case.

*A. I. E. E. Journal, Vol. XLI, 1922, March, p. 210.

In the remainder of the paper the author also seems to treat cases in which eq. (**4**) is not integrated in its general form, and no use is made of the empirical relationships between E and i, quoted at the very beginning of the paper. On the contrary, these relationships are deduced theoretically (Fig. 6).

While such a treatment may be valuable as a first approach to the subject and while the theoretical curves have considerable similarity with the actual oscillograms, a somewhat different approach, more in accordance with the physical facts of the passage of electricity through gases, is also desirable. The very purpose of the "General Case" treated at the beginning of the paper should be to indicate the solution of the problem for a given empirical relationship between E and i, and yet the author does not seem to use this method at all in his special cases. The equations between E and i, given at the beginning of the paper, are not even numbered for reference.

I therefore suggest the following alternative treatment of the general case: Since

$$d\,E/d\,t = (d\,E/d\,i)\,(d\,i/d\,t) \tag{a}$$

eq. (4) may be written in the form

$$L\,\frac{d^2\,i}{d\,t^2} + (r + d\,E/d\,i)\,d\,i/d\,t + i/c = 0 \tag{b}$$

or

$$\frac{d^2\,i}{dt^2} + \varphi\,(i)\,d\,i/d\,t + a\,i = 0 \tag{c}$$

where $\varphi(i) = 1/L\,(r + d\,E/d\,i)$ (**d**)

and $a = 1/(L\,C)$ (**e**)

The quotient $d\,E/d\,i$ may be called the ionization slope of a gas. It is a negative quantity which characterizes the reduction in the resistance of the gas with the increase in current. For solid metals at a constant temperature this factor is a positive constant and represents the ordinary ohmic resistance. Thus, the expression in the parentheses of eq. (**d**) may be called the *generalized resistance* of the circuit, and is one of the data of the problem.

The advantages of eq. (**c**) over Dr. Steinmetz's eq. (**4**) are as follows: (1) Eq. (**c**) contains only one dependent variable, i, as a function of t. Eq. (**4**) has two dependent variables i and E. (2) In Eq. (**c**) the given gas is characterized by its permanent and general physical property, $d\,E/d\,i$; in eq. (**4**) it is characterized by a specific variable factor $d\,E/d\,t$, which applies only to a particular circuit. (3) Eq. (**4**) apparently requires a complicated solution with $(4\,n + 3)$ simultaneous equations for the determination of the integration constants. Eq. (**c**) can probably be solved by assuming a simple algebraic function for $\varphi\,(i)$, and using a method of approximations. In fact $\varphi\,(i)$ may be assumed to vary in steps, in which case for each step $\varphi\,(i)$ is a constant, and the usual solution, of the form of eq. (**15**), holds true. (4) Eq. (**c**) can be reduced to a differential equation of the first order by putting

$$d\,i/d\,t = p \tag{f}$$

In this case

$$\frac{d^2\,i}{d\,t^2} = d\,p/d\,t = (d\,p/d\,i)\,(d\,i/d\,t)$$

or

$$\frac{d^2\,i}{d\,t^2} = p\,(d\,p/d\,i) \tag{g}$$

Eq. (**c**) becomes

$$p\;\;d\,p/d\,i + p\,\varphi\,(i) + a\,i = 0 \tag{h}$$

While I doubt if this equation can be integrated in the general form, certain plausible assumptions may possibly be made in regard to $\varphi\,(i)$ and p, to enable an approximate integration of this equation to be carried out, for practical purposes.

There are some minor statements in the paper which ought to be corrected. For example, the solution of a differential equation is called an integral equation; the latter term is used in modern mathematics in an entirely different sense. The

quantities C and q are called "integration constants" which they are not, being functions of the given circuit constants. The equation (7) may be a particular solution only, and nothing is said of the complementary function, such as the solution of case A. Eq. (4) is supposed to have only two constants of integration, being an equation of the second order; the statement that it has $4n + 3$ such constants ought to be explained more in detail.

Charles P. Steinmetz: I was considerably interested in Doctor Karapetoff's remarks, as I also tried to introduce the direct relation $\frac{d\,e}{d\,i}$ into the equations but found that the relations between e and i usually met in gaseous conduction—some of them being indicated in my paper—are such that the resulting differential equation cannot well be integrated. I therefore resorted to the method usual in such case, to represent the inconvenient relation by a Fourier series and use the first terms of this series. In other words, started from a special simple solution of the general equation and from this determined the conditions of the $e - i$ relation.

Speaking of the $2n + 3$ constants as "integration constants" in an obvious lapse; "indeterminate constants was meant.

The dynamic characteristic of the general $e - i$ relation I have introduced by the asymmetry of the $e - i$ relation adopted. In the oscillograms given in the paper, the frequency is sufficiently high to give a strongly marked dynamic form of the characteristic—the frequency is seen by comparison with the 60-cycle timing wave shown in the oscillograms.

THE EFFECTS OF MOISTURE ON THE THERMAL CONDUCTIVITY OF SOILS*

Shanklin, New York, N. Y., February 16, 1922.

D. W. Roper: As Mr. Shanklin stated, the British Research Association is doing similar work along these lines, and their results show some variations that were unaccounted for, and which, perhaps, may be solved by Mr. Shanklin's data.

Their tests were all made on buried cables, out in the open, where the effects of moisture must have varied from day to day, and the tests extended over a period of several weeks or months, and apparently it must have rained now and then during that interval, so I think that some of the variations they discovered and did not account for in the heating of the cables would be accounted for by Mr. Shanklin's data showing that the percentage of moisture in the soil has a considerable influence.

In the latter part of his paper Mr. Shanklin states that the work of the British Research Association should be supported by similar work in other countries. In this country we have had for two or three years a Cable Research Committee of which the speaker is the Chairman, and which is a sub-committee of the proper technical committees of the American Institute of Electrical Engineers, the National Electric Light Association, and the Association of Edison Illuminating Companies.

We have recently undertaken an investigation on the maximum permissible temperature of paper-insulated lead-covered cables, and we were prompted to do that by the remarkable differences of opinion which were expressed at the symposium on the subject before this Institute at the Convention a year ago. We have, therefore, secured a fund for research and have arranged with the Massachusetts Institute of Technology to conduct the investigation on this question of maximum permissible temperature, and it may be of interest to you to learn that the first check covering the expense of the research has been forwarded to the Massachusetts Institute of Technology, and we are meeting with the research men today to start the investigation.

R. W. Atkinson: The author has rightly emphasized moisture as of far greater importance than any other variation of soil conditions.

Until we have complete data of underground conditions, such as this paper shows to be necessary, in order to be safe when designing new underground systems we must estimate carrying capacities by taking into consideration the conditions of poorest present systems.

Data on these variables will make it possible to predict conditions, to design cheaper systems and help in their operation. If conditions are found unfavorable steps may be taken toward improving them.

W. A. Del Mar: It is somewhat difficult to see how this work of Mr. Shanklin's can be applied to practical use at the present time, because we have no control over the soil conditions or over the moisture conditions, so that in estimating the carrying capacity of cables, it is in general necessary to assume very bad conditions of soil conductivity.

There is, however, another property of the soil which is of considerable importance, and that is the thermal capacity or specific heat. The carrying capacity of a cable is very much influenced by the thermal capacity of the soil. Usually a cable is operated at its full load only for a very short period of the day—during the hours of peak load—and the thermal capacity is of great importance, because it determines the overload capacity of the cable during the peak period. It is unfortunate that Mr. Shanklin did not give the thermal capacity of the soil at the same time. It might possibly be derivable from histest data, even now.

In Europe, cables are very largely buried in the ground without being placed in ducts, and it is obvious that the influence of soil moisture will be greater in the case of such cables than in the case of cables in ducts, because in the latter case there is necessarily a more or less dry layer through which the heat must escape in getting from the cable to the soil. When armored cables are buried in the soil, and the soil is fairly moist the carrying capacity is surprisingly greater than in the case of cables laid in ducts in ordinary soil. I have not the figures with me, but they are available in existing literature, and in many cases it is worth while to look into the advisability of burying the cables directly in the ground to obtain the extra carrying capacity.

G. E. Luke: The determination of constants which limit the flow of heat is theoretically very simple; practically, however, such problems offer many difficulties and can be solved only by an untiring patience. This is especially so in this investigation described by Mr. Shanklin, where the unstability of the moisture content of the soil gave considerable trouble.

The conductivity curves Fig. 1 and 4 seem to indicate a decreasing thermal conductivity of the moist sand and soil as the heating continues. I take this to be due to a possible loss of moisture or a re-arrangement of the moisture in the material. Since the conductivity of dry sand clay soil was only 0.0028 w/cm.^{3} deg. cent. and that of water about 0.0057 it indicates that the high value of 0.014 to 0.020 obtained on the 15 per cent moisture mixture was due to convection currents in the water.

The rapid decrease of the co-efficient of thermal conductivity with increasing temperature gradients for the 15 per cent moisture mixture also indicates convection currents, since the heat transfer curve for a steam heated pipe in a tank of water has a somewhat similar shape. Due to this convection, it is probable that the co-efficient of thermal conductivity will depend to some extent upon the depth of the moist soil through which the heat is flowing. It would be interesting in this connection to explore the moist soil temperatures radially in the sample tested and thus be able to see if the co-efficient of thermal conductivity remained constant for various points distant from the heater.

The author mentioned the fact that some difficulty was encountered in the measurement of the inner tube temperature by the resistance method. The writer has had similar experiences in experimental tests and prefers to measure temperatures of such inaccessible places by thermocouples.

This investigation shows the possibilities of reducing the

*A. I. E. E. Journal, Vol. XLI, 1922, February, p. 92.

cable temperatures by moist soil. Of the other methods mentioned by the author the most promising ones are by the use of forced air or water streams through the cable ducts.

C. J. Fechheimer: The author states on the first page that it is possible by blackening the sheath to dissipate somewhat more heat. I wonder whether that was appreciable. The increase in heat dissipation due to blackening must come in consequence of the increase in radiation. I am of the opinion that the amount of heat that is dissipated by radiation is comparatively small, because the heat thus dissipated is proportional to the difference between the fourth powers of the absolute temperatures; and unless there be considerable differences in temperature, not much heat is dissipated by that means. In general most of the heat that is dissipated at ordinary working temperatures from cables or even from the outside surfaces of machines, or from self-cooled transformers, is brought about by natural or free convection currents of air, rather than by radiation.

This question of natural convection currents brings up a second point, namely, the influence of air pockets in affecting the thermal conductivity of almost any kind of material in which such air pockets occur. The influence of such air pockets changes very materially with their size. If the air pockets are very minute, heat that passes through them must flow by thermal conduction, whereas when they become of any considerable size, some natural convection currents are added. It is well known that if the air pockets are, say, one-tenth of an inch across more heat is transmitted by natural convection currents than by conduction. That is a very important point in all thermal conductivity problems; the influence of air pockets must be considered very carefully.

The author speaks of the size of the granules and states that the larger the granules, the better is the thermal conductivity. If I read his paper correctly, I understand him to attribute this to the fact that the volume of air which is entrapped between granules is smaller the larger the granules are. That probably accounts for some of the difference, but I am of the opinion that the thermal conductivity was altered more by the fact that with larger granules the air pockets were larger, and therefore the natural convection currents were considerably greater; consequently the apparent conductivity of the coil was increased.

It is interesting to note also, in Fig. 3 in the paper, the rapid increase in thermal conductivity as the percentage moisture is increased for the higher values of moisture. As water begins to displace the air particles that are trapped between the solid particles of the soil, the thermal conductivity is not increased very much—there are still enough air pockets to offer considerable resistance to the flow of the heat. It is only when the voids begin to become negligible due to the last water that is forced into the soil, that the thermal conductivity is raised considerably. Perhaps that may account for some of the discrepancies between Mr. Shanklin's tests and those of the authors to whom he refers.

The question of air pockets comes up very frequently, indeed, in engineering practise. For instance, in the building of houses it is well known if hollow tiles are used, and the air pockets are very large, the apparent thermal conductivity is fairly high; but if some finely divided material such as sawdust is put in, so as to make the individual air pockets quite small, then the thermal conductivity is materially increased, and less fuel is required to heat the building.

Nature has also taken care of this matter of air pockets in the manner in which some of the animals have been provided with clothing—for instance, the sheep with wool, or the duck with its type of feathers, eiderdown, both of which are known to possess very low thermal conductivity, for the reason that the air pockets are quite minute.

G. B. Shanklin: In reference to Mr. Roper's remarks, I am cognizant of the valuable work just started by his Cable Research Committee and am sure all members of the Institute anticipate great things from this work. Regarding the work of the British Research Association, Mr. Roper is right in accounting for some of the variations in results as due to moisture content of the soil. In any study of thermal characteristics, the distribution of moisture must be known, and preferably under control. This is particularly so where cable is buried directly in the ground.

I agree with Mr. Del Mar that parallel data on thermal capacity of soils containing different percentages of moisture are equally desirable. It is unfortunate that the procedure of our work made it impossible to obtain complete heating and cooling curves, necessary in determining thermal capacity. In a few cases we did get complete heating curves from which at least an approximate idea of thermal capacity can be derived. Without careful checking, however, these data could not be relied upon.

Mr. Fechheimer's discussion of air pockets is quite timely. It is generally recognized that they play an important part. In this respect the variations in thermal conductivity of paper insulated cables should be borne in mind. The degree of filling and looseness of lead sheath account almost entirely for these variations.

FIVE HUNDRED TESTS ON THE DIELECTRIC STRENGTH OF OIL*

(Hayden and Eddy), New York, N. Y., February 16, 1922.

C. E. Skinner: I have been familiar with the dielectric tests of oil for a good many years, and have personally made many thousand of tests, and have been familiar with many thousands of others, but I do not think I have ever had the idea that oil could be compared to air for uniformity as an insulating medium.

Oil has a very complicated chemical structure—it carries in it many impurities, and I have frequently observed the lining up of small impurities in the oil, such as fibers, etc., and have frequently noticed that if the potential is applied for a considerable period at a value somewhat below the instantaneous breakdown, breakdown will finally occur.

Relatively high values for a group of tests insures good oil, but low values may indicate accidental troubles with the test and not necessarily poor oil unless every possible precaution has been taken. It is for this reason that we have established an oil testing service with experts in charge.

A few years ago, we in the more or less fundamental study of insulation, wished to get some material which would be as nearly constant as possible, and we undertook, as did Mr. Hayden and Mr. Eddy, to use oil. We found that only with the most extraordinary precautions could we get anything approaching uniformity of results, such as to allow the use of oil as a standard.

In the commercial use of oil, we must expect a considerable variation in insulating value, and designs for its use must be so made that the average, or even the lower values, are those which are depended on, and used under extreme conditions and not those high values which can be obtained only with extraordinary precautions.

A. B. Hendricks, Jr.: It requires about 500 tests to prove anything regarding the dielectric strength of oil. The results of the present investigation are more erratic than usual, considering the care taken to obtain uniformity, but this may be explained by the form and small size of the spark gap used.

The maximum stress with a sphere gap is along the axis, hence is confined to a line, as contrasted with the large area of uniform stress between disks. This leads to a selective action instead of an averaging effect.

If the entire cylindrical volume of oil between the electrodes is considered as under stress, both volume and cross-section are much less than in the usual form of disk gap (about 1/7).

The authors state, "Usually the assumption has been made that the dielectric breakdown of oil . . . . is of the same nature and character as that of air." If so, the assumption was in error, as the ordinary factory and laboratory tests

*A. I. E. E. Journal, Vol. XLI, 1922, February, p. 138.

do not give an absolute value for the dielectric strength as with air, but an approximation to the probable average value, which should be interpreted as an indication of relative purity but not as an absolute value of dielectric strength.

The dielectric strength increases and approaches a maximum value as the amount of impurities decrease and this maximum may be taken as an absolute value, but oil containing impurities has no definite dielectric strength the results of tests being a matter of chance as pointed out by the authors.

These facts lead to uncertainty and dissatisfaction in the use of oil as a dielectric and cooling medium, but it is still the best and practically the only available material for the purpose (except gases), and the defects and variations are inherent and should be recognized.

The form of spark gap now in general use as a standard has as electrodes flat brass disks 1 in. in diameter with square edges and set 0.1 in. apart. I was responsible for the design and introduction of this form and desire to give some of the considerations which led to its adoption.

It is true that the voltage gradient is indeterminate and highest at the edges and can be calculated only for simple geometrical forms, as spheres.

This may be of theoretical interest but is of no practical consequence as the absolute dielectric strength of oil is indeterminate unless pure, which it never is, and depends on the tendency to a fortuitous collection of conducting particles in more or less continuous chains between the electrodes. The oil is kept in violent circulation between and near the electrodes, when approaching the arcing voltage, so that the chains are continually being formed and ruptured.

"It stands to reason, is a well known fact, and is obvious" that the stress is greatest at the corners and that the arcs tend to form there. The trouble with this imaginary statement is that it is only partly true, the actual effects being quite different from those which might be expected from superficial considerations.

Breakdown does not necessarily occur at points of maximum stress, as on corners, nor along the shortest path. It occurs at the time and place where the stress first exceeds the dielectric strength, the time element being important since the voltage is usually increasing at a rapid rate and the arcing voltage varies more or less inversely with time.

There is a large and nearly uniform field between disks and the effect of the edges seems unimportant in practise. I have just examined the disks from a standard spark gap which has been used for about 15,000 tests (one shot only on each filling) during the last two months. These show but slight burning from the arcs, which were confined almost exclusively to an area about ¾ in. in diameter at the center of the disk. A zone about ⅛ in. wide at the edge shows little evidence of arcing, but arcs occur quite frequently from the cylindrical surface. The samples come in quart cans, the spark gap being filled five times from each can, and one shot taken on each filling. The average of five shots is taken as representing the contents of one can. The ordinary variation of single shots from the average is about 10 per cent plus or minus and seldom exceeds 20 per cent. The maximum average value of five shots is about 40,000 volts, and there is reason to think that this represents closely the absolute dielectric strength of the oil for 0.1 inch, although the tests are between disks.

This form of gap was adopted as combining the greatest number of advantages after long experience with other forms and careful comparison with the previous standard which consisted of 0.5 inch disks 0.2 inches apart. The latter gap was used with a much larger volume of oil, it being standard practise to take five shots on one filling, stirring the oil before each shot. This older form (introduced by J. A. Capp) was used in determining the effect of water on dielectric strength, the resulting curve being widely published (See Pender's Handbook). In this test 11 points on the curve were determined, each by 5 shots on 8 samples or 440 shots for the curve, the results being quite regular and consistent and being duplicated at another time on a different kind of oil and by another operator.

The results gave a straight line on logarithm proper and the curve plotted from the resultant equation came on or near all the points.

The equations of the curve as originally given was

$$Y = 19.2\ X^{-0284}$$

where Y = breakdown voltage—kilovolts
and X = water—parts in 10,000 by volume.

The results may be expressed in round numbers, with sufficient accuracy by:

$$Y = 20\ X^{-1/3}$$

The regular and consistent results give confidence in the method. A careful comparison of this spark gap with the present standard one shows the latter to be fully as reliable but more sensitive. For 30 kilovolts in the old gap the new gives 15 kilovolts, but for higher values the new gap gives more than one-half the voltage. for lower values, less than one-half.

F. M. Farmer: Last evening the first discusser of the lightning arrester papers gave experimental evidence which apparently indicated that there is a certain minimum dielectric strength in all layers of air, irrespective of the thickness: that is, as the thickness of the layer is reduced, the puncture voltage falls, a minimum value is reached, and if the thickness is still further reduced, the breakdown voltage goes up again. Thus we have another example of our lack of knowledge of the molecular mechanics and the electrical breakdown of insulating materials.

Very recently a paper was published in England in which the dielectric stresses in cables is discussed. Experimental evidence is given which appears to show that the limiting feature is the minimum stress at the outside of the cable. and not the maximum stress at the conductor, which has been the most generally accepted theory.

Here, in this paper by Messrs. Hayden and Eddy, we have further experimental evidence of our lack of knowledge of just what goes on when solid and liquid insulating materials break down under dielectric stress. The phenomena and laws in regard to air are fairly well established, but our ignorance of solid and liquid insulations is very evident.

While this paper does not deal with the commercial testing of transformer oils for breakdown strength, I would like to call attention to a recent specification which has been issued by the American Society for Testing Materials. The electrodes and gap which were adopted for the dielectric strength test are one-inch flat disks with square edges and 0.1 inch separation. That standard was adopted after a series of tests involving something like 2200 determinations made by the Vacuum Oil Company, the Westinghouse Electric and Manufacturing Company, and the Bureau of Standards, in cooperation. A very careful mathematical analysis of the results by Dr. Silsbee of the Bureau of Standards showed rather conclusively that the most reliable results were obtained with one-inch disk electrodes spaced 1/10th inch apart.

Another feature of the prescribed procedure for this test is that five punctures are made on each of at least three specimens of a sample. If any one of the three averages differs from the grand average by more than ten per cent it is to be discarded and another specimen tested.

F. W. Peek, Jr.: The authors of this paper have done some very interesting work in applying the probability curve to the variation in the breakdown of oil. This apparently confirms the general belief that the variations are due to impurities. It is a well known fact that when a series of breakdown tests are made on a given oil with electrodes set at a small spacing there is very likely to be a considerable variation in the disruptive voltage. There is usually less variation when larger gap spacings

are used. For instance, with a 2-mm. gap the authors find a variation of $\pm$ 30 per cent from the average and 85 per cent between maximum and minimum. Tests that we have made show the same variation for the 2-mm. gap. With a 1-cm. gap, however, we find that the variation is $\pm$ 10 per cent from the average and 30 per cent between maximum and minimum. The variation may be much less even at small spacings, depending upon the condition of the oil and the type of the electrode.

While the variation is of theoretical interest, it is readily eliminated in practise. Skillful designers never use free oil spaces. Solid insulating barriers are always used between electrodes. Even with a 2-mm. oil space, which is smaller than is used in practise, the variation is cut in half by the insertion of a thin cambric or paper barrier between the electrodes. The variation is also less in practise because other types of electrodes than spheres are used. The spheres are the most useful electrodes in theoretical investigations because the dielectric field can be readily calculated.

The variation in free oil spaces is not surprising. There are a number or reasons why this variation should occur. In an oil gap under high stress there is the greatest degree of turbulence. The oil is forced back and forth between the electrodes. Another cause of variation is moisture and certain impurities in the oil. In a regular dielectric field the particles tend to line up along the lines of force and bridge between the electrodes. Moisture can, in fact, be separated from oil in this way and electrostatic separators have been devised and used. Occluded gases may also be a cause for low breakdown.

It is, of course, not necessary in practise to make 500 tests or even 100 to obtain the maximum, minimum and average characteristics of a given oil. The complete characteristics are in fact generally included in from 10 to 20 breakdown tests.

In practise oil is probably the most generally useful and reliable insulating material that is available.

John B. Whitehead: I have often wondered whether it would not be possible to get more uniform results on the dielectric strength of oil by observing the appearance of corona around a wire. In the case of a perfectly smooth wire in air, the appearance of corona is sharply marked, and even if the wire is soiled and has an irregular surface, it is very possible to separate the value of voltage at which streamers appear in the inequalities of surface, and the value at which corona appears more uniformly over the whole wire. It would seem to me that the same thing may be true of impurities in the oil, and that there might result greater uniformity of observations if it were possible to detect the appearance of corona in the oil. This detection of the start of corona is the only apparent difficulty.

Some years ago I set up in our laboratory an oil chamber in which a round wire was centered in a cylinder filled with oil, with the idea of studying the appearance of corona in the oil. The work was stopped largely because of the pressure of other matters, and because I ran into the difficulty of not being able to tell in a dark oil just the value of voltage at which the corona appeared uniformly. However, it would seem to be possible with little effort to obviate this difficulty. The apparatus mentioned used an optical method. A beam of light of high intensity passed through the oil and close to the surface of the wire. It is probable that a variation in the optical constants in the oil will be found in the presence of corona. I am quite sure that Mr. Hayden and his associates have worked with the corona in oil, and I think it would be interesting to have their opinion upon this suggestion.

Delafield DuBois: During 1905, I attempted a research on the dielectric strength of oil to determine the relation between dielectric strength and temperature. I found the same difficulty experienced by Hayden and Eddy, namely, that it was not possible to get consistent results for any given condition, and therefore I was not able to obtain exact data to show the variation of dielectric strength due to changes of temperature. But there were certain observations made during those experiments that may be of interest.

Breakdown voltages apparently increased as temperature increased. But on several mornings after the oil tank had been cooled over night, undisturbed, the first test gave a higher breakdown voltage than any made with the oil hot. This was taken to indicate that moisture was normally present in the gap, so that when the oil was heated the effect of this moisture became less, due to some kind of absorption by the oil, but that when cooling, undisturbed, the moisture condensed upon the sides of the tank, leaving the gap free from moisture.

With the oil cold and perhaps slightly moist, the well-known partial breakdowns of the oil gap, were, of course, noted. As to the breakdown at short intervals, and in order to study this phenomenon, the following experiment was made: With a needle gap set fairly wide, there were interposed in the gap, two parallel partitions of cheesecloth, dividing the gap into three equal parts. These cheesecloth separators were brought up flush with the surface of the oil, and on the surface of the oil a thin paper was floated. The bubbles rising from the gap were thus held under the paper, and indicated in what part of the gap they originated. It was noted that often the bubble was from the middle section of the gap only. This suggested that streamers of moisture were building out from the electrodes and that the breakdown was from their ends. It is obvious that these premature breakdowns do not become total breakdowns, because the moisture baths are at once dissipated by the passage of the current. However, when the breakdown between the ends of the streamers is half the oil gap, it is probable that the breakdown of the remaining half will follow. This explains why only a little moisture in the oil lowers the dielectric strength by half, or more than half, if the current of breakdown is not limited by resistance in series with the gap. The resistance of these moisture streamers and the series resistance of the testing set are two factors in determining breakdown. It is remarkable that such streamers should exist at all under the violent motion due to an electrostatic stress; undoubtedly all moisture brought into the field by the moving oil is captured and strongly held. Dry oil is, of course, not absolutely free from moisture, and under stress this moisture would accumulate in the gap, giving erratic results in any such tests as those made by Hayden and Eddy.

Carl Hering: In liquid conductors of mixed composition, as in some electric resistance furnaces, the so-called pinch-effect, which is an electro-magnetic force tending to crush the conductor radially,—has the peculiar property of tending to move the better conducting material to the central axis of the conductor; thus a rod of copper floated on a channel of mercury will be sucked down to the middle axis quite violently when a sufficiently large current flows.

This force is electromagnetic, it may be that a similar electrostatic force exists also, which tends to move the materials of lower dielectric strength into the more direct path of the disruptive discharge. The authors admit that such materials may exist as they no doubt exist in the form of disconnected particles, a uniformity of the results cannot be expected.

C. P. Steinmetz: The disruptive strength of insulation is one of the most important in electrical engineering.

Since the early days it was suspected that there is a definite dielectric strength similar to the rupturing strength of mechanics, although experience did not seem to confirm this.

For air, this matter was finally cleared up by the work of Mr. Peek, Dr. Whitehead and others, who proved that in air there is a definite disruptive strength which determines the breakdown of an air gap, but that the action is complicated by two additional phenomena, the energy distance and the time lag, and that these additional phenomena account for the disagreements in previous investigations.

Since that time, the same assumption has usually been made, and the conclusions and results on the disruptive strength of

air gaps, have been transferred and applied to liquid and solid insulating material, such as oil, although such applicability was not proven, and experience did not well agree with the application of the laws of the disruptive strength of gases to liquid and solid dielectrics.

As I understand it, the object of Mr. Hayden's and Mr. Eddy's paper is to investigate the laws of disruptive strength of oil and the existence of a definite disruptive gradient which determines the breakdown of the oil gap, and to ascertain whether the laws of the dielectric strength of air can be applied to oil and solid insulation. The paper shows that such is not the case, and that the phenomenon of dielectric breakdown in oil or solids is different from that in air, since under conditions where an air gap gives constant results, as has been found by observation, an oil gap gives results scattered by the probability law over a range many times greater than the possible error. It also shows that the breakdown in oil and in solids is subject to additional phenomena which do not exist in air, and therefore the subject, in view of its importance, requires more extended and further investigation.

In my opinion, the results of the paper are not intended to apply to the problem of the commercial test of oil, but they deal with the question whether there is a definite breakdown strength of oil, and whether this breakdown strength determines the electrical behavior of oil. It seems to me the conclusion which must be drawn from the paper is that there probably is a definite breakdown strength of oil, but that the commercial and industrial behavior of oil is not determined by this breakdown strength, but that the actual breakdown of oil is very much below its probable dielectric strength, and is determined by a probability law—by which the impurities or whatever we may call it— determine the actual breakdown strength.

It seems to me that the additional data given in the discussion rather corroborate this conclusion by showing that where the tests are made under such conditions, that each test averages up, as by having a large section of oil gap, or great lengths of the oil gap, or barriers, etc., so that each individual test thus averages a large mass of oil, then the variations under the probability law necessarily are less, that is, the results are more consistent. As however, the paper does not deal with the commercial testing of oil, but with the question of the existence of a definite dielectric strength of oil the test had to be made under conditions where you have a definite gradient so as to know what you get, and where the gradient is as uniform as possible. This means a sphere gap. Therefore when the matter is further investigated by other investigators, I especially wish to draw this to their attention, and ask them to utilize the sphere gaps, and utilize them under conditions where the surrounding elements are as uniform as possible.

N. S. Diamant: I would like to ask the authors to tell us, if possible, the kind of oil used in these tests. It would be also well to know what some of the physical and chemical characteristics of the oil in question were. They go into a lengthy and welcome description of electrical test methods explaining how the voltage readings were accurate to within less than 1 per cent. However, it would be very useful to the profession to know also what kind of oil behaved as erratically as the oil under question. It seems to me this paper is an excellent example of how investigations should not be conducted. Personally, I can see nothing in their mathematical gymnastics and probability curve. These are very interesting elementary mathematics to my mind, but it would be very interesting to know the per cent of moisture in this oil and some of its physical and chemical properties.

It seems to me that the fact that the average breakdown voltages for the successive five sets of hundred tests was, $e_0 = 95$, 96, 91, 89, 86 shows fairly definitely at least for the sample under consideration, an increasing deterioration.

Now I would like to ask the authors if they can tell us what kind of oils show this erratic behavior for the first fifty or one hundred tests; also what they may expect in the way of average per cent variation in the values of successive disruptive voltages. As to the cause of the variation between the different successive values of breakdown voltages, I am sure they will agree that we will have to look more into the mechanism and theory of breakdown and its effect on the physical and chemical properties of oil.

J. Slepian: The authors contrast the uniform dielectric properties of air with the more erratic behavior of liquid insulating medium such as oil. With the great development in the past decade of the theory of ionization by collision in gases, a clear insight has been obtained into the mechanism of breakdowns in gases. The reasons for the uniformity of breakdown of airgaps under ordinary conditions are well known and it is even possible to produce special conditions in which airgaps will break down in quite as erratic a manner as the oil gaps described in the paper.

According to the theory of ionization by collision, electrons or charged molecules, called ions, when moving in a gas under a sufficiently high gradient may, by their impact with neutral molecules, break these latter up into new positive and negatively charged ions. These newly formed ions, if the gradient continues to be maintained, may also generate more ions by collision. Thus, starting with only a few charged particles in a gap, by the application of a sufficiently high voltage great conductivity may be developed. After a considerable number of these ions have been produced, due to the opposite directions of travel of the positive and negative charges and also their different velocities, space charges develop in the gap and the electrostatic field becomes distorted. The gradient becomes greatly increased in some portions of the gap and it then becomes possible to maintain the ionization by collision process with much lower voltage than was required to initially break down the gap.

It may be shown that for plane electrodes, for any gap length in excess of a certain length which is very small for air at atmospheric pressures, there exists a critical gradient such that any initial ionization, however small, will be so greatly multiplied by ionization by collision that the uniformity of the electrostatic field will be disturbed and the gap broken down. This gradient may properly be called the breakdown gradient of the gap.

Now, there are two requirements necessary if the gap is always to break down at this gradient. First, there must be some initial ionization, for otherwise there would be nothing to start the ionization by collision process when the breakdown gradient is applied. This initial ionization in practical spark gaps is produced by ultra-violet light and penetrating radiations which exist normally in the atmosphere. If this initial ionization is reduced to a very small amount by enclosing the gap in a dark chamber for the time for the ionization to build up sufficiently to unbalance the electrostatic field may become quite large. Thus, Townsend in his "Conduction in Gases" states that for a gap enclosed in a dark chamber a voltage in excess of the normal breakdown voltage may be applied for several seconds before breakdown occurs. Hence, under these conditions, a gap tested under rapidly increasing voltage would show erratic breakdown values.

The other requirement for uniform breakdown properties is that the initial ionization must not be too great. For then even with fields too weak to normally produce a great multiplication of ionization by collision, the space charges developed by the initial ionization may so greatly distort the electrostatic field as to produce an excessive gradient in some portion of the gap, and in this portion a rapid multiplication of ions by collisions may occur. Thus we all know that if a gap is so situated that the ionized vapors from a nearby arc reach it, the breakdown voltages become erratic with abnormally low values.

Ordinarily there will not be a high density of ionization in air because of the high mobility of the ions. They rapidly diffuse away from the spot where they were generated, and are quickly lost by recombinations between the positive and negative ions.

Hence an airgap may be given successive tests with fairly short intervals and still not show any progressive weakening.

We do not know whether all these considerations can be carried over to a liquid dielectric like oil but it seems very likely. Some recent work of German physicists showing that ultra violet light increases the conductivity of ordinary insulating materials, points fairly definitely to an ionization process. In any case, if the mechanism of breakdown in oil is at all similar to that of air, we can very readily see why the breakdown of oil should be more erratic. For the ions in oil must have a very low mobility, partly because of the very great viscosity of the medium in which they move, and partly because of the great tendency for polymerization in liquids, so that the individual ions consist of slow moving large groups of molecules. Hence the rate of diffusion must be very slow, so that it is possible to have spots of high ion density and spots of low ion density, with only feeble equalizing tendencies.

Ionization may also persist for a long time because of the slowness with which positive ions and negative ions will meet and neutralize each other. Hence, any slight ionizing agent will produce a relatively large density of ions because this will be determined by the equilibrium when as many ions are lost by recombination as are being generated by the ionizing agent.

The feebleness of the forces tending to make uniform and small the initial density of ionization are quite enough to explain why the breakdown of a small oil-gap is erratic. Add still further the turbulence of the oil under stress, which may at any moment in a haphazard fashion sweep a highly ionized portion of oil into the gap, and the wideness of the probability curves obtained by Messrs. Hayden and Eddy are no longer to be wondered at.

The point which I wish to bring out in this discussion is that there may be no fundamental difference between the mechanism of breakdown of an air gap and an oil gap. The apparent difference is one of degree only and due to the high mobility of particles in air. If air gaps were tested with voltages applied for very short times, say fractions of a micro-second, the results would probably be as variable as those obtained for the oil gap and conversely, if the oil gaps were tested by the application of continuous voltages for very long times, say hours, quite uniform results should be expected.

THE USE OF SUPERIMPOSED IMAGINARY E. M. F'S., CURRENTS AND FLUXES IN THE SOLUTION OF ALTERNATING-CURRENT PROBLEMS*

(KARAPETOFF), NEW YORK, N. Y., FEBRUARY 16, 1922

R. E. Doherty: The scheme presented in this paper is highly useful, not only to electrical engineers, but also to mechanical engineers—indeed, useful in any problem which involves sine functions of time and in which the transient term is not of importance. And even if the transient is important, the particular solution of the permanent condition can be written down easily by this method. Making this possible, it certainly must be regarded, as the author says, a useful engineering "tool."

The paper does not emphasize sufficiently either the utility or the limitations of the scheme. For it is merely a scheme like other mathematical schemes, such as Heaviside's Operator, which works in some cases and not in others.

Of the three types of problems illustrated in the paper, the first is, I think, the most important in respect of the number of problems encountered in engineering, although of course its value in the rarer types 2 and 3, is also shown. And it is the former type to which the application of the method is the simplest. The author reviews how the addition of an imaginary term of equal magnitude to the real term, that is by the addition say of

$$j\,E \sin(\omega t + \gamma)$$

to

$$E \cos(\omega t + \gamma)$$

gives the vector identity,

$$E\,[\cos(\omega t + \gamma) + j \sin(\omega t + \gamma)] = E\,\epsilon^{j(\omega t+\gamma)}$$

that is, a vector of constant magnitude and rotating by the time angle ωt. Making a similar addition to each sinusoidal time variable in the problem, and substituting in the differential equation gives,[1] as each term, the product of a scalar quantity and a unit vector of the exponential form

$$\epsilon^{j(\omega t+\gamma)}$$

But $\epsilon^{j(\omega t+\gamma)} \equiv \epsilon^{j\gamma}\,\epsilon^{j\omega t}$

By thus separating out the time angle unit vector $\epsilon^{j\omega t}$ in each term, the vector may be canceled out of the equation, leaving only the product of a scalar, say E or I, and a stationary unit vector $\epsilon^{j\gamma}$ or $\epsilon^{j\alpha}$, where γ and α are phase angles of these vectors with respect to a common reference. The process therefore starts with the problem expressed as trigonometric functions of time, and ends with the problem represented as a system of staionary vectors.

Following out the process as applied to equation (**5**), gives

$$j^2\,\omega^2 L\,I\,\epsilon^{j\alpha} + j\,\omega\,r\,I\,\epsilon^{j\alpha} + I/C\,\epsilon^{j\alpha} = j\,\omega\,E\,\epsilon^{j\alpha}$$

Taking voltage as zero vector, and substituting $j^2 = -1$,

$$-\omega^2 L\,I\,\epsilon^{j\phi} + j\,\omega\,r\,I\,\epsilon^{j\phi} + I/C\,\epsilon^{j\phi} = j\,\omega\,E\,\epsilon^{j\phi}$$

where ϕ = phase angle between voltage and current.

Using vector notation,

$$\dot{E} = E\,\epsilon^{j\phi}$$
$$\dot{I} = I\,\epsilon^{j\phi}$$

and solving

$$\dot{I} = \frac{\dot{E}}{r + j(\omega L - I/\omega C)}$$

which is equation (**6**). But it should be remembered that E in (**6**), although the same notation as in (**1**), is nevertheless a vector in (**6**), but scalar in (**1**).

From the foregoing equations, it is obvious that *the process is equivalent to the substitution, directly in the differential equation, of*

$$\frac{d}{d\,t} = j\,\omega$$

and writing the variables as vectors.

That is, representing $\frac{d}{d\,t}$ by the usual notation p,

$$p = j\,\omega$$
$$p^2 = -\omega^2$$
$$p^3 = -j\,\omega^3 \quad \text{etc.}^2$$

In other words, the solution is immediately written down without, in each case, going through the process of substituting the imaginary term: which process, I fear, may appear to be necessary both from the text and the analogs given. The possibility of the above direct substitution would not, I think, be obvious from the paper to most engineers unfamiliar with these forms.

As to the limitations of the method: none is stated except that the variables against time shall be sinusoidal; but there are limitations which I believe are not obvious. A mathematical equation is applicable only under the assumptions it contains. In the present case, the fundamental assumption is that imaginary terms shall remain imaginary, and real terms, remain real. Thus no products must appear, since two imaginary terms multiplied together give a real product. I would therefore ask the Author: since in the method, each variable contains an imaginary component, does it not follow that, unless new definitions are added, the method is applicable only to *linear differential equations involving sinusoidal functions of time*; that is, it is *not*

*A. I. E. E. JOURNAL, Vol. XLI, 1922, January, p. 11.

1. Since either the differential or integral of an exponential is again the exponential.

2. This was proposed in 1917 by Mr. A. Press in discussion of paper by V. Bush on "Oscillating Current Circuits," A. I. E. E., Vol. 36, p. 207.

applicable, without new definitions, to equations involving products of variables, or products of a variable with the differential coefficient.

I mentioned at the outset that the method is useful in mechanical engineering problem. An illustration is the design of flywheels for reciprocating engines or compressors connected to synchronous machines. The equation[3] of the system of forces is

$$I \frac{d^2 \theta}{d t^2} + T_d \frac{d \theta}{d t} + T_s \theta = f(t)$$

where

I = moment of inertia of rotating masses.

θ = mechanical angular displacement from a reference, rotating at the average, or synchronous, speed.

T_d = damping torque, corresponding to a phase shift at the rate of 1 mechanical radian per sec.

T_s = synchronizing torque, corresponding to one mechanical radian displacement.[4]

$f(t)$ = applied force as function of time. It is the fluctuating component of the crank effort; that is, the difference between the total impressed torque and that which is consumed as load and friction. Although of complicated form, it is resolved into a Fourier's Series, and each sinusoidal component considered separately.

Thus applying the method proposed in the paper,

$$- I \gamma_n^2 \dot{\theta} + j \omega_n T_d \dot{\theta}_n + T_s \dot{\theta}_n = \dot{T}_n$$

where $\dot{T}_n$ and $\dot{\theta}_n$ are respectively the vector force, and vector displacement angle of the nth harmonic. Thus

$$\dot{\theta}_n = \frac{\dot{T}_n}{j \omega_n T_d + (T_s - I \omega_n^2)}$$

the phase angle between the force and displacement being

$$\phi = \tan \frac{\omega_n T_d}{T_s - I \omega_n^2}$$

Each component is thus computed, and plotted as waves to determine maximum.

I therefore consider the method proposed in the paper as a very important mathematical device, and have hoped by this discussion to encourage its greater use.

J. B. Whitehead: Methods of solution of differential equations are of especial interest in two connections, one when a new type of equation presents itself for solution, and the other when teaching the phenomena whose sequence is expressed by the form of the equation.

The complete solution of the simple a-c. circuit, the first example used by Professor Karapetoff in calling attention to the method of superposed imaginaries as an aid to solution, has been known for years. Consequently its chief value here must be only as an illustration of a mathematical method. However, there is an element of danger in the use of the method in this case, since it does not lead to the complete solution of the equation of the simple a-c. circuit. The transient term on closing the circuit does not appear and is neglected. As is well known, there are many instances in practise when this term is of great importance. Professor Karapetoff clearly recognizes this, and will doubtless reply that the exponential form may also be used for the complete solution, but in this case, as he well knows, all the simplicity of method to which he calls attention disappears. Therefore, for the purposes of teaching, in this case the method appears to me to have little value and, in fact, to be open to criticism. Its brevity and simplicity make a powerful appeal, but it does not completely cover the problem. While I have had the method in my notes for a number of years, as have many other teachers of this subject, I have avoided using it, feeling that in doing so I would shirk a measure of responsibility in not giving the complete solution.

In the second example the author is on very much surer ground. He presents an apparently new equation which demands solution. Here the simplicity of the method has apparently facilitated the solution, leading to conclusions which it was possible to check in practise. I have not read the original paper describing the experiments and I think it would be of interest if Professor Karapetoff would say a further word as to the agreement between the results to be expected by the solution of the equation and those noted in actual observation.

In the third case we have again a problem whose solution has been known for some time. The method therefore should be considered from the point of view of its usefulness in explaining the phenomenon involved. I confess that I do not see its value for obtaining the intensity of a gliding or rotating magnetic field due to a polyphase system of electromotive forces. The various transformations through which the author has to proceed in order to obtain the result, seem to me to confuse the comparative simplicity of the physical relations underlying the type of field in question as related to the circuits setting it up. By use of the ordinary complex expressions for the several electromotive forces, and their successive resolution into two directions in space, lead to simple series for the two sets of components which can be immediately evaluated in single terms. This method described by Steinmetz in one of his early works has the advantage of keeping clearly before us the simple elements of the exciting circuits and the resulting magnetic intensity.

Thus, while recognizing the simplicity and beauty of the method as applied to new unrecognized problems, I question its value for the purposes of explaining the phenomena represented by the equations.

P. Trombetta: The fundamental principle upon which all calculations of electric circuits are based, is that the constants of the circuit remain unchanged after an e. m. f. is applied to it. In Prof. Karapetoff's exposition it is tacitly assumed that the constants of the circuit remain also unchanged if we apply, instead of a real e. m. f., a complex one and since the application of a complex e. m. f. yields an easier solution, it is better to study the circuit by the application of a complex e. m. f. rather than a real e. m. f. If we replace the word e. m. f. by the word force, which may mean any kind of force whatsoever, and if we replace the word circuit by the word system, we have the generalized theorem that: the study of a system, which by the application of a force gives rise to oscillations and losses of energy, is always simpler when the force applied is sinusoidal and can be expressed as an exponential function of time. As generalized above, this method may be used for the study of oscillations of flywheels, in the study of fluid circuits and of all like systems.

W. V. Lyon: If I understand Prof. Karapetoff correctly he is, in effect, making a plea for the vector method of solving alternating-current problems rather than that method in which the instantaneous values of the quantities are represented by trigonometrical expressions. As a mechanism for solving problems in which the electromotive forces and currents vary sinusoidally a comparison of the methods soon convinces one of the superiority of the vector method. Unfortunately, as Prof. Karapetoff says, it is not widely appreciated to what extent the vector method may be used. We are all familiar with its application to the steady conditions in simple electric circuits and in a-c. machinery, and perhaps to a lesser degree, in long transmission lines. Moreover, it is exceedingly useful in the solution of the current distribution in round wires or in rectangular armature conductors, and of the flux distribution in transformer laminations. In these cases the angular velocity of the vectors is a real number. The letter "ω" is usually used. Rather recently it has been appreciated that the vector method

3. Equation (1) in paper on Flywheels, A. S. M. E. December 1920, by R. E. Doherty and R. F. Franklin.

4. Obviously no such displacement could occur within operating limits. It is simply a proportionality factor which holds approximately in the limits considered.

can also be applied to the solution of the transient conditions that are obtained in transformers, synchronous and induction machines. This latest application gives an exceedingly powerful and simple method of attack. In the problem of the transient condition the angular velocities of the vectors are not real, but may be represented by complex numbers of the form $(-\alpha + j\,\omega)$. The ω gives the real angular velocity of the vector and the α determines the rate at which it shrinks exponentially.

While Prof. Karapetoff has made no direct plea for the vector method the writer has so chosen to interpret his argument. The symbolism $E\,\epsilon^{j\omega t}$ has been used to represent a rotating vector by mathematicians for many years, long before the notation was introduced into electrical engineering. There are, moreover, other simpler and just as powerful vector notations. The solution for the current density in rectangular armature conductors is very simply expressed in terms of hyperbolic functions, more simply the writer believes than in the manner Prof. Karapetoff suggests. The two treatments have of course a marked similarity on account of the relation between hyperbolic and exponential functions.

If we assume that the applied e. m. f's. vary sinusoidally, with either constant or damped amplitudes, and the circuit constants do not vary, all resulting currents will vary sinusoidally as do the applied pressures. In such a case we might well agree that it was superfluous to indicate this obvious variation. There can be no doubt but that this apparent lack of any convention to represent sinusoidally varying currents and pressures is extremely simple.

The writer looks upon it as fortunate that we have a variety of symbolisms that may be used in the solution of problems inasmuch as the student may choose for himself the method that best suits his understanding. Those who are not familiar with the notation that Prof. Karapetoff presents are thus indebted to him for bringing to their attention so powerful a method. After all, the best mechanism for the individual student to use in solving problems is that which is not only simple to manipulate but which keeps before him most clearly the physical reactions involved.

V. Karapetoff: Mr. Doherty is right in saying that in practical applications, in linear differential equations, is it perfectly safe to use $j\,\omega$ in place of $d/d\,t$ and $-\omega^2$ in place of $d^2/d\,t^2$.

This is, however, not a substitute method but a direct result of expressing the current as an exponential function. In equations involving products of complex quantities, if one of the quantities is simply an exponential impedance operator which does not contain time, the method is still applicable. But if an equation contains a product of an exponential current and an exponential voltage, the result is a double frequency power and a constant average power. A new convention is then necessary as to the interpretation of the results.

Dr. Whitehead doubts the advantage of the exponential notation when the transient term is not negligible. He will find Section IV of Dr. Steinmetz's book on "Transient Phenomena" treated in the exponential form to a good advantage. As to the third illustration in my paper, E. Arnold in his Wechselstromtechnik solves the same problem by means of sine and cosine functions, and I believe that a comparison will show a decided advantage in favor of the complete notation.

Training to Think Versus Gathering Information

BY TALIAFERRO MILTON
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THE time allotted to me is not sufficient for me to go into details of how I have arrived at my conclusions, and I will, therefore, content myself with the expression of some of my opinions.

Many professional educators may not agree with me and I shall be very glad indeed to debate the subject with them in such detail as cannot be used in this short summary of my opinions.

I regret that I have not any very useful suggestions of a constructive nature to offer to educators in regard to what should be done to correct and improve the systems of education now in use in this country. If, however, these mere expressions of opinion will serve to stimulate the professional educators in discovering cures for the evils which are patent to many of us engaged in practical every-day work, then what I have to say will be worth something.

I do not claim any originality in these opinions; in fact they have been formed not only through my own personal observations, but through many discussions with other work-a-day men with whom I have come in contact. I left the educational field because I did not think I was suited to it, and all I can do is to point out to professional educators evils for which they may, through their study and experience, find a cure.

The crime of most of the colleges today is that they do not teach their students to think. They spend too much time in cramming facts into the student's heads when, in my opinion, the short four years available to the average student for college life is all too little time for teaching the student to think. After all, it really doesn't matter very much whether a young man in the early 20's leaving college, knows a great deal of a concrete nature, provided he has learned to think.

It is of course, necessary that certain fundamental principles be taught; moreover, they should be drilled into the heads of the students, but beyond that, the work to be performed by a student should always be laid out with the one idea in mind of increasing the student's capacity and ability to think. Why should time be wasted in college, in shop work? What does it matter whether or not a young fellow, graduating from college, can file a flat surface or do a good blacksmithing job, or a hundred other odd mechanical jobs, unless the doing of such jobs is entirely incidental to the training of his thinking apparatus? Suppose he *is* a fair mechanic when he leaves college—he will find in the shops mechanics who have never even been through high school who are ten times as good as he is at a

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hundred different jobs. These mechanics who have had little schooling have learned every step in their trade in an empirical fashion and I have known some of them who were crammed full of a thousand and one facts some of which were not true. Not long ago I was talking to an older man about a certain young fellow, and I remarked that this young man seemed to have had a lot of knowledge. The older man answered, "Yes, he knows a lot, but unfortunately most of it isn't true."

Several of the cleverest engineers with whom I am acquainted spent most of their time in college on one piece of research work and when they started their careers as engineers, they were very *very* "green" from the shop-man's and practical engineer's viewpoint. They had practically no acquaintance with the thousand and one details of shop equipment, central station equipment, etc. However, the particular piece of research which each had done had involved a great deal of study and thought and in completing this research they had learned to think. Before making the research, they had, in each case, been thoroughly drilled in the fundamental underlying principles of mathematics and physics which were the tools they used in thinking out the problem in hand. The fact remains that (without going into further detail of how I have arrived at these conclusions) these men today *are* great constructive engineers. I know other men who have never had any college education who are also great engineers and I find that they are great thinkers.

I go so far as to believe that if a man is born a great thinker it matters not whether he has any college education. Some extreme examples are John Marshall, the great Chief Justice, and Abraham Lincoln, the great "Emancipator" and President. These men, to be sure, were not engineers, but I think none of us doubt that had they turned their hand to engineering instead of law and politics they would have been just as successful in the engineering field as they were in their chosen professions. Those of you who have read biographies of these men, especially the recent "Life of John Marshall" by Senator Beveridge, cannot help but be impressed with the fact that even though these men obtained very little standard education in the common schools and colleges they did get in their particular scheme of study and work a tremendous training in how to think.

Right here I want to say that I believe there should be no fundamental difference between the general methods of engineering education and education for any other profession. All education for the young man during his school and college courses should be with the one idea in mind—to increase his capacity for thinking straight, thinking clearly and thinking energetically through each problem to a conclusion. Once he has acquired such a habit, each problem will be conquered as it arises regardless of how much concrete knowledge on the subject one has to start with. This reminds me of a definition of an engineer which was given to me some time ago by an engineer who is a member of this Institute. He said, "An engineer is one who learns how to do something before the people find out that he doesn't know how." It is obvious that he couldn't function in this manner unless he were trained in the fundamental principles and knew how to think.

No one could claim that an exact knowledge of a great many facts is in itself detrimental. My whole contention is that the time is so short in the grammar school, high school and college that the teaching of empirical knowledge should not crowd out the training in the thinking processes and it has been my direct observation that that is exactly what has happened to a large percentage of college graduates. Their minds have been crammed full of facts and they are unable to think clearly. A man taught a lot of facts can only copy work previously done. He will never build anything new, unless along with these facts he has learned how to think. He cannot produce synthetic results because he cannot think things out to a conclusion. He has become mentally lazy because others have done his thinking for him and have supplied him with the finished result in the form of a fact.

A student, even if he starts with an inclination to think will soon abandon effort in that direction if he is drilled by his professors to accept their teachings as immutable laws. The student should be trained at all times to keep his mind open. He should never be allowed to accept any working hypothesis as an indisputable law. The best picture I know of the danger of teaching students that the working hypotheses which we now accept as laws are indisputable and immutable is contained in the French astronomer Flamarion's little story, at the end of his chapter on the LaPlace Nebula Hypothesis. Those of you who are not familiar with this story will, I am sure, get something out of it and I recommend that you look it up.

The overemphasis which, in my opinion, is being given to the laboratory method seems to have extended backward into the high school and grammar school. I say extended backward because I believe that the prodigious use of the laboratory method now in vogue in the grammar and high schools is because of the entrance requirements of the colleges. I have a fine opportunity just now of observing the methods in the grammar school because I have two children in one of the finest public grammar schools in America. It certainly seems to me that the laboratory method is being overworked.

While I believe that a large part of the trouble with most of our college graduates today is due to the waste of time in teaching them facts, I would like to point out what, in my opinion are other indirect causes of the student's lack of thinking capacity. One of the main troubles with modern colleges, especially the large ones is the lack of democratic spirit. Above all things we should make the college really democratic

and drill into the student's heads that all they obtain at college is a training in the groundwork and the fundamental principles and the process of real thinking so that when they leave college they are ready to *start* life's work. The college student, who starts life's work with an idea that because he has been to a certain college he is better than other men has a serious handicap and he loses several years in getting a fresh start.

Some years ago I sent my business card into the office of a young engineer who had quite an important position with a large concern in the northwest. He came out into the reception room and his greeting was, "Are you a salesman or an engineer? I do not care to talk to a salesman; I want to talk to one of your company's engineers." I asked him, "Are you an engineer?" and drawing himself up stiffly, he said, "I am a graduate of —" (naming one of our largest and best known engineering colleges). I had difficulty in restraining the explosion which began to accumulate in my insides. I got to be quite friendly with this fellow but I learned in a short time that he was not an engineer at least not one in accordance with the definition I have given above. It so happens that the college he was graduated from has turned out a great many thinkers, but I have often wondered whether they learned to think at college or whether they were just born that way, or whether some good old-fashioned teacher in the grammar or high school started them off right so that even the college couldn't ruin them. *Lack of the democratic spirit is not conducive to clear thinking.*

A college should teach modesty. Most modest men are thinkers. Perhaps that's the reason they are modest and perhaps I am mixing up the cause and effect.

I have in mind several of the smaller colleges in this country who are turning out men, the great majority of whom seem to be able to think; and in looking around for a cause of this I have noticed that the men at these colleges work. The athletic and social side is not over exaggerated as it is in some of the larger and wealthier colleges. If the athletic and social functions are made of too much importance, a man hasn't time to think. When he isn't attending a football game or a dance, he is trying to cram up sufficient "*facts*" to pass his examination.

Everything that is said above could apply as well to any other form of education as it could to engineering education and I believe that other branches of education are just as derelict in these respects as is the modern form of engineering education.

Some of the college courses for engineers are, however, even worse than the college courses for other professions in that they slur over the teaching of English, literature, philosophy and history. I know some pretty good, practical engineers who are college graduates and who get pretty good results, but who are almost illiterate. I do not believe that many of us agree with one of our most prominent automobile manufacturers that such education is useless. Certainly those of you who agree with me that the main principle of education should be enhancing a man's thinking capacity cannot admit that a broad education is not necessary in an engineering course. What can stimulate the thinking powers more than a good general knowledge of literature, philosophy and history?

Summing up, it is my firm opinion that in the United States today we are overdoing empirical, shop and laboratory practise in our educational institutions all the way from the beginnings of the kindergartern through the university. I believe that by overdoing these methods we are cramming the student's minds instead of enlarging them.

Teach the student to think and give him just such facts as are necessary to make him think.

CORRESPONDENCE

REMUNERATION OF ENGINEERS

To the Editor:

Permit me to comment upon an attitude of engineers as frequently voiced in the columns of Engineering Journals. It is the attitude of injurious modesty whenever the question of salary is raised, that I wish to animadvent upon.

There generally seems to be a tendency on the part of engineers to slight the significance of monetary remuneration, and the spokesmen of the engineering societies exhibit a desire even to further that tendency. "Hints on Job Getting," may be mentioned as an instance where such a spirit is shown. Undoubtedly this accounts for the fact that the engineering profession is paid very poorly; only after prominence and much experience is gained, can an engineer hope to earn a decent living.

This is not a healthy state of affairs. Many engineers do teaching as a side line or in some other way endeavor to earn an additional dollar. It stands to reason, that being occupied thus, at all times, such an engineer is unable to keep pace with the progress of his profession or to perfect his knowledge by supplementary reading. Is it any wonder then, that a number of engineers are not of the first class?

In the suggestions on the education of the engineer, many propose a more thorough or more practical course of study in the college in order to produce abler engineers. I, however, maintain that the student days in college are too short to affect materially the nature of the engineer by a change in the studies. The only way to obtain better engineers, is to encourage a continuation of study after leaving college and this can be done very effectively by *not* ignoring the salary. The engineering class, like any other class does not consist purely of idealists—the majority, I think, long for a comfortable living. (Neither is it advisable to keep a man from pondering over his empty purse by dinning idealism in his ears). At the conventions of physicians, higher fees are determined upon; for the benefit of all concerned, the engineer should at least, make a similar demand.

JACOB KATZMAN.

Light Without Glare

BY WARD HARRISON

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The object of this paper is to show what factors must be controlled in order to produce satisfactory illumination without glare.

The relative importance of brightness of light sources, their candlepower, position in the field of view and contrast with the background are discussed. The paper includes tables from the Illuminating Engineering Society Code of Industrial Lighting in which for the first time various light sources, both natural and artificial are classified from the standpoint of glare. The use of these tables is explained and illustrative examples are given.

ARTIFICIAL lighting is an old art, so old in fact, that one's mental attitude toward it is influenced largely by tradition if not by heredity. How many there are who still judge the desirability of a lighting unit simply by its whiteness and dazzling power, criteria which served well in the days when vegetable oil lamps and tallow candles were the only light sources available and when perfect combustion, as evidenced by a brilliant white flame, was a phenomenon altogether too rare. There are many also in whose minds the thought of excessive heat is associated as the inseparable accompaniment of a high level of artificial illumination; they forget that the 200-candle power lamp of the present generates no more thermal units than did a single candle in the days of our forefathers. And as to the question of expense in lighting, it may be added that the cost per hour for the 200-candle power lamp is today only about equal to that of the aforementioned candle. In this connection, it is not without interest to take cognizance of the apparent anomaly, that, for some locations artificial light has actually become cheaper than natural light. For example, a number of our larger public buildings and even our art galleries have found it much more satisfactory and in the end less expensive to provide for the use of artificial light exclusively rather than to assume the high initial cost and the up-keep expense of large areas of exposed skylight.

It would be interesting also, to turn aside and see how modern developments have made it possible for our great industries to have daylight levels of illumination, and daylight quality of illumination, available throughout the twenty-four hours and ordinarily at the very moderate expenditure of from 1 per cent to 2 per cent of their labor cost. Just what this means, just what the difference is between 1 to 2 foot-candles, the old levels of artificial illumination and 10 to 20 foot-candles, the daylight level of interior lighting must be seen to be appreciated. One who has tested out for himself his acuity of vision and the difference in his speed of perception under these different levels of illumination has no difficulty in understanding why production invariably falls off with fading daylight in the great majority of our older and inadequately lighted industrial establishments; and how even a night shift in these same plants can be made profitable if proper lighting is supplied.

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On the other hand, almost every one of the invaluable developments of modern applied science, such for example as the high-tension transmission of electric power, or the gasoline motor car, has brought its own particular hazards and a capacity for serious abuse. High power artificial light sources, or for that matter, modern prism glasses for the control of daylight, are no exceptions to this rule. Unfortunately, it is true that the potentialities of the newer lamps as aids to progress are only one-half utilized or appreciated and, by the same token, their flagrant abuses have for the most part been allowed to run along unchallenged. A typical machinist substitutes for his old stubby candle an unshielded incandescent lamp of 100 times its power and 1000 times its brilliancy; remarks, perchance, that it is such a fine light that it almost blinds him; and calmly goes on with his work for as many days as his eyes—or the law—will allow him.

FIG. 1—GLARING LIGHT FROM UNSHADED LOCAL LAMP WHICH IS A MENACE TO SAFETY AND TO VISION

Now it is obvious that bare 100-watt lamps on drop cords will cause serious glare, that raising the lamp a foot or two above the direct line of vision, or perhaps enclosing it in a white diffusing globe will mitigate the harmful effect, but just what is the quantitative value of each of these factors, and just how far one must go to obtain reasonably satisfactory conditions for vision, are subjects regarding which there is still much lack of uniformity of opinion.

It is generally accepted that for a fixed position of light source the degree of glare experienced is a function of (a) brightness of the source—candle power per unit area; (b) total flux of light directed toward the eye from

the source—candle power in the direction of the eye; and (c) contrast in brightness between the light source and its background. Authorities differ greatly as to the relative weights to be assigned to the three quantities and formerly (a) and (c) were particularly stressed. More recent investigations have, however, pointed toward the total flux of light which reaches the eye from a light source as being the most important single factor in the production of glare.

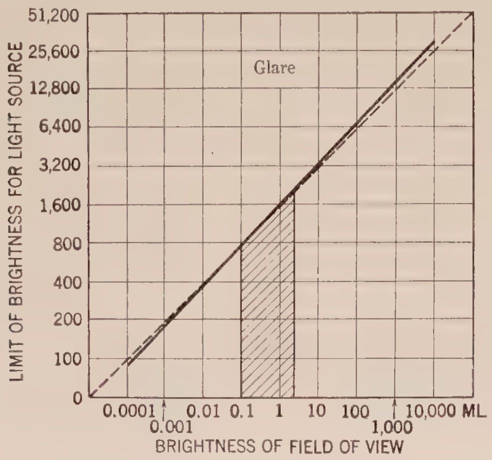

Fig. 2—Nutting's Data on Limits of Brightness

I. Dr. Nutting[1] found (see Fig. 2) that with a fixed area of light source at a fixed distance from the observer, increasing the brightness of the surroundings tenfold only permitted of approximately doubling the candle power (and brightness) of the source if no increased sensation of glare were to be experienced. In other words, the final contrast between the source and its background must be reduced to one fifth of its former value if it is desired to double the candle power of the source.

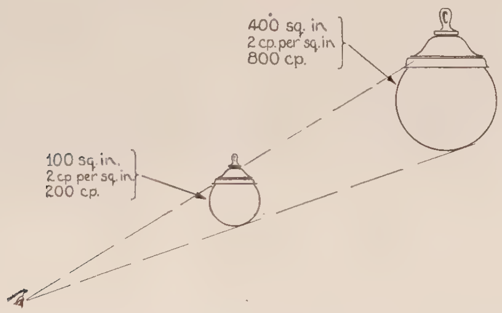

Fig. 3—Doubling the Distance between the eye and Light Source Permits of Increasing the Candle Power Four Times

II. From the results of other investigations[2] it can be deduced also that one may approximately double the candle power of a source having a fixed location if the area of that source is increased 10 times, which, of course, involves decreasing its brightness to one-fifth of the former value. It will be observed that in this case as in the preceding one, the resulting contrast between the source and its background is reduced to one-fifth in order to double the candle power of the source, without increasing the glare effect.

III. It is obvious from a consideration of Fig. 3, that if the brightness of the light source and the brightness of its background are both held constant and the distance between the eye and the source is doubled it will be permissible to quadruple the candle power of the source, since the brightness of the image on the retina will be the same in both cases and the diameter of the source is doubled to hold the area of the retinal image constant.

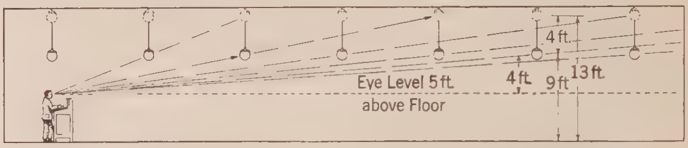

Fig. 4—Raising the Mounting Height of the Light Sources Well Above the Eye Level is the Greatest Single Factor in the Reduction of Glare

IV. If after doubling the distance between the eye and the light source and at the same time increasing the candle power and area four times to preserve the glare balance it is decided to cut in two the candle power of the source in this new position, it is then permitted by (II) to cut the area of the source to one-tenth and by cutting the candle power again in half the area may again be reduced to one-tenth so that with the candle power of the source the same as when in the first position close to the eye, the area of the source need only be 1/25 of that required by the first position. It may be said then that doubling the distance between the eye and a light source permits of dividing its area (and increasing its brightness) by 25.

These four illustrations should serve to make clear the major importance of candle power and distance from the eye, in a word "flux entering the eye", rather than the brightness or contrast as the dominant factors in glare. In truth, small bare incandescent lamps are under some circumstances really less obnoxious than frosted lamps of say five times the candle power used in the same location.

Formulas, in which these various relations are expressed algebraically are included in the Appendix. It should be borne in mind that the avoidance of glare is

1. B. G. Nutting, *Transactions I. E. S.*, Vol. XI p. 939.

Dr. Nutting's data show that if the candlepower of the source and the brightness of the background are both raised indefinitely, in this logarithmic ratio, a point is finally reached at which the brightness of the background is as great as that of the source. This point, which might be termed the glare limit, represents the brightest surface on which the eye can focus without immediate discomfort no matter what the surroundings. This brightness is approximately 50,000 millilamberts or about five times the brilliancy of white cardboard exposed to full sunlight.

2. Ward Harrison, *Transactions I. E. S.*, Vol XV p. 34.

still far from being an exact science and the numerical values in these formulas may require very material revision as a result of later investigations.

As a specific application of these relations, take the case of a lighting installation in a large office devoted to bookkeeping in which the lamps are suspended in glass diffusing globes four feet above the eye level (about nine feet above the floor) and in which the contrast between the units and the walls which form their background is found to be about 25 times too great for comfort. If no change is to be made in the size of the lamps the trouble can be remedied in any one of three ways.

(a) The brightness of the globes can be reduced to 1/25th of the former value by increasing the diameter of the globes five times.

(b) The brightness of the background can be increased 25 times by painting it a lighter tone and directing more flux toward it.

(c) In accordance with IV the units can be raised four ft. or to a height of eight ft. above the eye level (thirteen ft. above the floor—see Fig. 4).

Where the head room is sufficient this latter method certainly presents the easiest solution of the problem. In fact, the importance of locating interior lighting units well up toward the ceiling cannot be over-

FIG. 5—SPECULAR REFLECTION OR GLINT MAY SOMETIMES PROVE AND AID TO VISION ESPECIALLY IN STREET LIGHTING

emphasized. In street lighting, where, in nearly all cases the lamps are seen against an almost perfectly black background the need for high mounting is even more urgent.

The first comprehensive tabulation in which various light sources, both natural and artificial, are classified as to glare and in which proportionate weight has been given to the location of the source in the field of view, is included in the Illuminating Engineering Society's revised Code of Lighting. This Code was prepared by the Society to make available authoritative information for legislative bodies and others who are interested in regulations covering lighting and it also serves as a guide for factory owners and operators in improving the lighting conditions in their own plants. The Code is now an American Standard indorsed by the A. I. E. E. and many other national organizations. Tables III, IV, V and VI and the appended matter are reprinted from the Code.

TABLE III.
CLASSIFICATION OF LIGHT SOURCES FROM THE STANDPOINT OF GLARE

Grade I indicates sources of maximum softness.
Grade X indicates sources of maximum harshness.

Maximum Visible Brightness	Total Candle Power in Direction of Eye				
(Apparent candles per sq. in.)	Less than 20	20 to 50	50 to 150	150 to 500	500 to 2000
	Grade	Grade	Grade	Grade	Grade
Less than 2	I	I	II	II	III
2 to 5	II	II	III	IV	V
5 to 20	II	III	IV	VI	VII
20 to 100	IV	V	VI	VII	VIII
100 to 1000	V	VI	VII	VIII	IX
1000 and up	VI	VII	VIII	IX	X

In Table III, Light Sources are classified from the standpoint of glare, taking into account both the maximum visible brightness and the candle power in the direction of the eye. However, it is not con-

TABLE IV.
SPECIFIC CLASSIFICATION OF LIGHT SOURCES FROM THE STANDPOINT OF GLARE AS DERIVED FROM TABLE III
NATURAL LIGHT SOURCES
(As seen through windows or skylights)

	Grade
Sun	X
Very Bright Sky	V
Dull Sky	III
Sun Showing on Prism Glass	IX
OPEN GAS FLAMES	II

Incandescent Mantle Gas Lamps

	Mantles consuming 2-5 cu. ft. per hr.	Mantles consuming 5-8 cu. ft. per hr.	Large single mantle or cluster 8-12 cu. ft. per hr.	Large single mantle or cluster 12-20 cu. ft. per hr.	Cluster or high pressure lamp consuming above 20 cu. ft. per hr.
	Grade	Grade	Grade	Grade	Grade
Clear Glassware	V	VI	VII	VIII	IX
Frosted Globes	III	IV			
6-in. Opal Globe*					
8-in. Opal Globe*	II	III	IV-VI		
10-in. Opal Globe*	I	II	III-V	V-VII	VI-VIII
12-in. Opal Globe*					
Dome Reflector					
Mantle Visible	V	VI	VII	VIII	IX
Mantle not Visible	I	II	III	IV	IV
Bowl Reflector					
Mantle Visible	V	VI	VII	VIII	IX
Mantle not Visible	II	II	III	V	V
Totally Indirect*			I-II	II	III
Semi-Indirect Bowls*			II-III	II-IV	III-VI

*Where a range is given the best grade, that is the lowest, applies to globes that are evenly luminous, and the poorest to globes which have a decidedly bright spot in the center.

TABLE IV—*Continued*

ARC LAMPS

	Grade
Enclosed arcs, clear globes	IX
Flame arc, clear globes	X
Flame arc, opal globes	VII-VIII
MERCURY VAPOR TUBES	VI
CARBON AND METALLIZED FILAMENT INCANDESCENT LAMPS	
8 c. p.	V
16 c. p.	V
32 c. p.	VI

Tungsten Filament Incandescent Lamps

Watts	10-25	40-60	75-100	150-200	300	500-1000
Bare Lamps	Grade VI	Grade VII	Grade VIII	Grade IX	Grade IX	Grade X
Frosted Lamps or Frosted Globes	II	III	VI	VII	VIII	
8-in. Opal Globes*	I	I-II	II-IV	IV-VI		
12-in. Opal Globes*			II-III	II-V	IV-VI	VII-VIII
16-in. Opal Globes*				II-V	IV-VI	V-VII
Flat Reflectors—Filament Visible	VI	VII	VIII	IX	IX	X
Dome Reflectors—Steel or Dense Glass	VI	VII	VIII	IX	IX	X
Filament visible from working position	I	I	III	III	IV	VI
Filament not visible from working position						
Bowl Reflectors—Steel or Dense Glass	VI	VII	VIII	IX	IX	X
Filament visible from working position						
Filament not visible from working position	II	II	III	IV	VI	VII
Dome Reflectors—Bowl-Enameled Lamps			IV	V	VI	VI
Semi-Enclosing Units*			III-IV	IV-VI	IV-VII	VI-VIII
Totally Indirect Lighting*			I-II	I-II	II	III
Semi-Indirect Bowl*			I-III	II-III	II-IV	III-VI

*Where a range is given, the best grade, that is the lowest, applies to globes that are evenly luminous, and the poorest to globes which have a decidedly bright spot in the center.

venient in most cases to make the measurements necessary to determine which class a light source is in according to this table. Therefore another table has been shown in the Code, Table IV, in which specific light sources upon which the measurements have been made are listed with their grades.

Table V, Chart of the Field of View, classifies light sources according to their position in the field of view,

TABLE V.

CHART OF THE FIELD OF VIEW

Classification of Position of Light Source Which Takes into Account the Distance from the Eye and the Angle of the Line of Vision.

Height above Floor in Feet	Horizontal Distance of Light Source from Observer in Feet 1	2	3	4	6	8	10	12	16	20	25	30	35	40	50	60 & up
6.5 or less	A*	A*	A	A	A	A	A	A	A	A	A	A	B	B	B	B
6.5 - 7	G	E	D	C	C	B	B	B	B	B	B	B	B	B	B	C
7 - 8	G	G	F	E	D	D	C	C	C	C	C	C	C	C	C	C
8 - 9	G	G	G	F	F	E	D	D	C	C	C	C	C	C	C	D
9 - 10	G	G	G	G	F	F	E	E	E	D	D	D	D	D	D	D
10 - 11	G	G	G	G	G	F	F	F	E	E	D	D	D	D	D	D
11 - 12	G	G	G	G	G	F	F	F	F	F	E	E	D	D	D	D
12 - 13	G	G	G	G	G	G	F	F	F	F	E	E	E	E	E	E
13 - 14	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E	E
14 - 15	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E
15 - 16	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E
16 - 17	G	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E
17 - 18	G	G	G	G	G	G	G	G	G	G	G	G	F	F	F	F
18 - 19	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	F
19-20 and up	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

*Classified as A unless light source is so nearly above the head of operator as to be quite outside of field of view in which case classify as E.

TABLE VI.

SHOWING LIMITING GRADES OF LIGHT SOURCES PERMISSIBLE FOR VARIOUS LOCATIONS

Classification of position	Space or work to be lighted. Roadways and yard thoroughfares	Storage spaces aisles, stairways, handling coarse material	Ordinary manufacturing operations†	Offices and drafting work and certain mfg operations*
	Limiting Grade	Limiting Grade	Limiting Grade	Limiting Grade
A	VI	V	III	II
B	VII	VI	V	IV
C	VIII	VII	VI	V
D	IX	VIII	VII	VI
E	IX	IX	VIII	VII
F	X	X	IX	VIII
G	X	X	X	X

BACKGROUND

Where the background and the surroundings are very dark in tone, a light source of one grade softer than that specified in Table VI may be required. Where the background and surroundings are very light in tone one grade more harsh than that specified in the table may sometimes be permitted.

†For the present the limits set in this table cannot be rigidly applied to portable lamps used for temporary work such as setting up machines repairing automobiles, etc.

*Those operations in which workers are seated facing in one direction for long periods of time.

TABLE VI-A.

SHOWING GRADES OF LIGHT SOURCES WHICH ARE CONSIDERED GOOD PRACTICE FOR VARIOUS LOCATIONS

Classification of position	Space or work to be lighted: Roadways and yard thoroughfares	Storage spaces aisles, stairways, handling coarse material	Ordinary manufacturing operations	Offices and drafting work and certain mfg. operations
	Grade	Grade	Grade	Grade
A	IV	III	I	I
B	V	IV	III	II
C	VI	V	IV	III
D	VII	VI	V	IV
E	VIII	VII	VI	V
F	IX	IX	VIII	VI
G	X	X	IX	VIII

i. e., their horizontal distance from the observer, and their height above the floor. To be glaring, a light source must either be located in a position close to the eye or, if at a distance, it must lie within a small angle from the ordinary line of sight. Light sources in positions denoted by the first letters of the alphabet in Table V are close to the eye or close to the line of vision, and are most likely to be the cause of discomfort. Light sources in positions *E*, *F* and *G* are farther from the eye or without the direct line of vision and are less likely to cause glare.

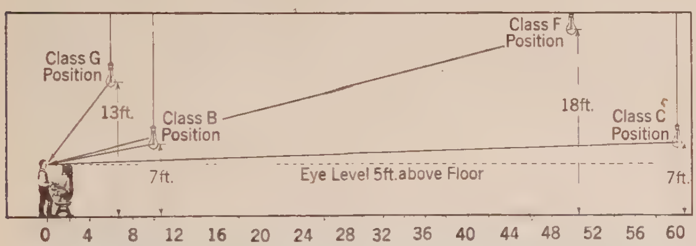

FIG. 6—TYPICAL POSITION GIVEN IN THE CHART OF THE FIELD OF VIEW, SEE TABLE V.

Table VI of the Code combines Tables IV and V and shows the limiting grades of light sources permissible for various types of work, when the light sources are located in the different positions in the field of view.

In addition Table VI-A which is not contained in the Code has been computed. This table shows the Grades which are recommended for various conditions. It should be used in preference to Table VI in planning new installations and in all other cases, except when the question is simply one of whether the lighting system is acceptable from the legal standpoint.

These tables may appear formidable, however, they are in reality very simple to use as may best be demonstrated by trying them out in one or two examples. For instance, consider the lighting in the machine shop of an industrial plant which is being inspected to find whether it comes within the requirements of the lighting code.

Because of the very low ceiling the lighting system which had been recommended by a competent engineer for this shop consisted of *R L M* dome reflectors with 150-watt bowl-enameled lamps mounted 8½ ft. above the floor and spaced 10 ft. apart. The owner of the plant, however, decided that he would save himself a little trouble by using clear lamps instead. Otherwise the lighting was installed as recommended. A number of machinists work in this room. Their work does not keep them in one position for a long period of time.

The inspector found that the most troublesome light source from the point of view of any one workman was the second[3] unit directly in front of his machine, at a horizontal distance of ten to twelve feet. Referring to Table V, the inspector found that for units located at a height of eight to nine feet and a horizontal distance of ten to twelve feet their position in the field of view is classified as *D*. By referring to Table IV, he also found that a dome reflector and 150-watt clear lamp the filament of which is visible, is classed in Grade IX, and again, that in Table VI under the column headed "Ordinary Manufacturing Operations" in the fourth line, opposite *D*, the harshest grade of light source which it is permissible to use is given as Grade VII. The lighting system in this plant, therefore, did not meet the Code requirements as far as provision against glare was concerned and the inspector's position was that the owner of the shop must change the lighting and he suggested that bowl-enameled lamps be installed as originally recommended. According to Table IV dome reflectors with 150-watt bowl-enameled lamps fall in Grade V which is well within the Code requirements and which, incidentally, is the grade of source which Table VI-A mentions as representing good practise for this class of service. It is of interest to note that one large manufacturing concern which recently rehabilitated its lighting found in the course of experiment that not only did the substitution of bowl-enameled lamps for clear lamps provide greatly increased comfort for the employes but it also resulted in a measurable increase in production in the departments where the change was made.

The following explanatory notes for the guidance of inspectors and industrial plant operators are taken verbatim from the I. E. S. Code.

"From Table IV the majority of bare incandescent lamps are seen to have a relatively poor rating; that is, most of them fall in Grades VII to IX, and it is evident from Table VI that Grades VII to IX are never to be permitted in work rooms in positions *A*, *B* or *C*. That is, the use of bare incandescent lamps is prohibited in working areas except when they are located at considerable heights above the floor or when they are so placed as to be out of the field of vision. At the present time it will be found necessary from a practic-

3. With a flat reflector the third or fourth unit ahead might have caused still greater discomfort on account of its closer proximity to the line of vision but with an R. L. M dome at a height of eight feet to nine feet the lamp filament in these more distant units is cut off from view by the skirt of the reflector.

able standpoint to delay the strict enforcement of this provision in a very few instances, particularly in the case of extension cord lamps used in temporary work, such as in setting up machinery and in repairing automobiles, etc.

FIG. 7—AN AMPLE SUPPLY OF SOFT WELL DIFFUSED LIGHT AND PARTICULARLY FREEDOM FROM SHADOWS IS REQUIRED FOR DRAFTING ROOMS

"It will be noted from Table IV that the sources of natural light, side and ceiling windows, usually fall in Grade IV. This means (see Table VI) that no mandatory rules are established as to the use of shades, awnings, etc., except in those cases where the sky is visible through portions of the sash in position *A*, that is, less than 6.5 ft. above the floor, or where the sun itself comes within the range of vision.

"However, Grade II is the limiting value for light sources less than 6.5 ft. high, in offices, and other locations where the workers are seated facing in one direction for considerable periods of time. Hence, in these cases, to comply with the Table, the work must be so arranged that the employees are not required to face windows where the sky is visible through the lower sash; that is, less than 6.5 ft. above the floor.

Prism glass when so located as to catch the sun's rays ordinarily has a very much poorer rating than clear glass; hence, where it is used the installation of window shades or curtains should ordinarily be required.

"*Glare by Reflection.* Another way in which glare is produced is by the reflection of light from polished surfaces in the field of vision. The difficulty experienced in protecting the eyes from this kind of glare is sometimes very great. The brightness of the image on the working surface is, of course, proportional to the brightness of the light source above it, and hence one way in which to minimize this effect is to diffuse the downward light; that is, to use a bowl-frosted, or bowl-enameled lamp or an enclosing fixture, or to employ semi-indirect or totally indirect lighting fixtures. In some cases the light source can be so located that its reflection is directed away from, rather than towards, the eyes of the workers. The avoidance of highly polished surfaces in the line of vision is another good way to minimize reflected glare.

"There are some instances, on the other hand, where sharp shadows and specular reflection from the materials worked upon actually assist vision. For example in sewing on dark goods the thread is much more easily distinguished when illumination is secured from a concentrated light source, such as a brilliant lamp filament, which casts sharp shadows and gives rise to a distinct glint from each thread. However, in these cases the light source must be particularly well shielded from the eyes of the worker."

Lest in his efforts to minimize glare one should arrive at the conclusion that the best way of all to accomplish this purpose is to extinguish the lamp, the following quotations from the closing paragraphs of the Code are also included.

ADVANTAGES OF GOOD ILLUMINATION

"While the advisability of good natural and artificial illumination is so evident that a list of its effects may seem commonplace, these effects are of such importance in their relation to factory management that they are worthy of careful attention. These effects of good illumination, both natural and artificial, and of bright and cheerful interior surroundings, include the following:

FIG. 8—AMPLE ILLUMINATION WITHOUT GLARE

"1. Reduction of accidents.
"2. Greater accuracy in workmanship, resulting in improved quality of goods.
"3. Increased production for the same labor cost.
"4. Less eye strain.
"5. Greater contentment of the workmen.
"6. More order and neatness in the plant.
"7. Supervision of the men made easier.

"While it is difficult to place a definite money value on the savings effected in increased production and improved quality, by good illumination, it by no means follows that such savings are insignificant or unsubstantial. The factory owner who ignores them neglects his own interests. Other items in the foregoing list, even more difficult to value definitely, are none the less real; taken together, they constitute a powerful argument in favor of the best available illumination."

Appendix

Let a_1, a_2 represent area of light source
b_1, b_2 represent brightness of background
c_1, c_2 represent candle power of source
d_1, d_2 represent distance from source to eye

I. Where the area of the source and its distance from the eye are held constant and the candle power of the source is varied then to maintain equality as to glare

$$\frac{b_2}{b_1} = \left(\frac{c_2}{c_1}\right)^{\frac{1}{\log 2}} = \left(\frac{c_2}{c_1}\right)^{3.3}$$

II. Where the brightness of the background and the distance from the eye to the source are held constant and the candlepower of the source is varied then

$$\frac{a_2}{a_1} = \left(\frac{c_2}{c_1}\right)^{\frac{1}{\log 2}} = \left(\frac{c_2}{c_1}\right)^{3.3}$$

III. Where the brightness of the source candle power per unit of area and the brightness of the background are held constant and the candle power of the source is varied then

$$\frac{d_2}{d_1} = \left(\frac{c_2}{c_1}\right)^{\frac{1}{2}} = \left(\frac{c_2}{c_1}\right)^{0.5}$$

IV. Where the candle power of the source and the brightness of the background are held constant, and the area of the source is varied then

$$\frac{d_2}{d_1} = \left(\frac{a_1}{a_2}\right)^{\frac{\log\sqrt{2}}{\log 5}} = \left(\frac{a_1}{a_2}\right)^{0.216}$$

V. Where the brightness of the background and the area of the source are held constant and the candlepower of the source is varied, then

$$\frac{d_2}{d_1} = \left(\frac{c_2}{c_1}\right)^{\frac{1}{2-2\log 2}} = \left(\frac{c_2}{c_1}\right)^{0.71}$$

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

COST OF ADEQUATE STREET LIGHTING*

A recent survey showed that 15 years ago approximately 5.4 cents out of each dollar of municipal taxes was the average amount expended for street lighting in cities of 30,000 population or larger in the United States. In the face of the need for much better lighting, the amount allotted to the street lighting for the same cities in 1919 had fallen to an average of 3.8 cents. In an article commenting upon the comparatively small expenditure for this essential public service, Mr. A. F. Dickerson reported that the average per capita expenditure in cities is only about $0.70 annually for street lighting. The highest found was $4.81 per capita, and in 50 of the best illuminated cities there was an average of $2.04 per capita.

It is probably not sufficient to compare street lighting expenditures on the basis of population alone, since in cities having the same population there may be a considerable difference in the number of miles of improved streets. Possibly a fairer method of comparing street lighting appropriations is to base the computation on the length of paved streets. Even on this basis there are many variables which should have weight. Some of these are the layout of the city, the width of street paving, whether current is distributed overhead or underground, and the local cost of labor and materials entering into construction. However, the following tabulation indicates the order of annual cost per running foot of street:

Class of Streets	Annual Cost Per Foot of Street
Business District	$1.00 to $4.00
Thoroughfares, Manufacturing Districts, Boulevards	.25 to 1.00
Residential Street	.15 to .60
Outlying Districts and Alleys	.05 to .20

The lower range of figures applies to systems involving a minimum outlay for installation and in general providing minimum levels of illumination. The upper range of expenditure in most cases permits an adequate installation consisting of underground distribution, supplying ornamental lamp standards of substantial design and properly spaced to obtain maximum effectiveness of illumination.

The initial investment for installation of circuits and equipment is a factor which affects the design of street lighting in a greater measure than it does interior lighting. Especially where the service to the lamp is carried underground, as is becoming more and more the practise for new installations in progressive cities, the fixed charges on the investment for equipment may

* Extract from a paper by Earl A. Anderson presented at the Twenty-Seventh Annual Convention of the American Society for Municipal Improvements, October 25-28, 1921, Baltimore, Maryland.

actually form half the total annual cost of the system. However, the cost of installing the duct and cables, the cost of the lighting standard and fixture, and some of the costs of maintenance, such as cleaning and repair to equipment, increase but little for the larger sizes of lamps as compared with smaller. There is consequently a distinct economy in cost per unit of light in adopting the larger lamp sizes. For example, in the case of a series underground supply to an ornamental lighting system, the annual cost of a 1000-c. p. lamp is only of the order of twice that of a 250-c. p. lamp even though the larger lamp supplies four times as much light.

In view of the insufficiency of municipal appropriations it became quite common several years ago for individual groups of property holders to install sections of improved street lighting with ornamental equipment at private expense. However, because of the difficulty of insuring a continuance of proper maintenance under this plan, and also because of the recognition of the importance of this lighting as a municipal improvement, present practise is very distinctly in the direction of having the city handle contracts for the installation and operation of all street lighting. Particularly in business districts the city may assume the entire cost of the system in view of the benefits accruing to the city as a whole. In other cases, a large part of the cost of special lighting may be charged back to abutting property under the laws in many states which permit the establishment of special improved districts in which assessments are made for the street lighting in the same manner as for the paving and other necessary street improvements.

CROSSING BEACONS

BY L. C. PORTER

In the days of the horse-drawn vehicle a simple danger sign sometimes supplemented by a bell furnished adequate warning at dangerous crossings, such as railroad grade crossings, etc.

Today with the enclosed automobile limousine traveling at much greater speed than the horse and with many other trucks and cars having relatively noisy engines, the sign and bell are inadequate. Crossing gates and a watchman with a flag are improvements, but even that does not give a warning that has a punch to it; one that causes an approaching driver to sit up and take notice.

Signals that will accomplish this have been developed by using a flashing light in back of a red lens. Numerous tests have proved that a flashing light is very much more effective as a warning than a light burning steadily. The first general application of such warning beacons were to highway crossings, where the municipality could not afford a traffic officer. Later, they were used to supplement officers and in various other dangerous places. These beacons consisted of a flashing gas flame operating from a tank of compressed gas. Round diffusing globes were used and later lenses. The next application was to railroad grade crossings and here electric lamps operated from primary or storage batteries. The battery is placed underground and will operate the signal without any attention, for periods of one year or more. The lamps are made to outlast the battery and for assurance against burn-out are renewed when the battery is renewed.

As the small electric lamp used in this service (about 100-volt, ¼-ampere) does not need the ventilation required by a gas flame, the lenses are being replaced by much more efficient parabolic reflectors, utilizing a slight percentage of the total light flux from the lamp. This combination projects a warning far down the road both by day and by night that is so conspicuous and so positive and reliable that it cannot be overlooked.

The effectiveness of these warning beacons is attested by the fact that the State of Massachusetts has permitted them to replace the gatemen at grade crossings.

For general use along the highways the warning light is also being used to illuminate route signs. A system of colors has been worked out to indicate whether the beacon is at a cross road, a turn, a dead end, etc. In many instances the beacons carry advertising material on the standard and lighted ads on the rear of its signal. Here devices are proving so effective and so popular that they will unquestionably, have a rapid growth throughout the country.

A NEW USE FOR MINIATURE LAMPS

Miniature lamps can be used to advantage for so many different purposes that seldom a day passes without some new use for them being discovered. Probably the very latest field of application found for these lamps is in lighting the thermometers in poultry incubators.

For several years incubator owners have realized that opening the incubators several times daily to read the thermometers was not the best thing in the world for the eggs. However, with most incubators this was the only way by which the temperature of the interior could be read accurately. Holding the flashlight or burning match outside the door-window to read the thermometer has always proved unsatisfactory—in many cases the glare from the glass window made the thermometer more difficult to read than without this light.

Several of the largest thermometer companies are now manufacturing electrically lighted thermometers for incubators, while some incubator manufacturers are using them in initial installations. The equipment consists of a thermometer equipped with a flashlight lamp, battery, and switch. The thermometer, lamp, and battery are installed inside the incubator, and the switch on the outside; when a reading is desired, it is necessary simply to close the circuit by means of this switch. With such an outfit the user will not lose a considerable amount of heat, and perhaps some of his chicks, every time he reads his incubator thermometer.

Rating of Cables in Relation to Voltage

Bibliography on Dielectrics

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THIS bibliography was prepared at the request of the Subcommittee on Wires and Cables of the Standards Committee of the Institute, and is intended specifically to be a continuation of that published by E. H. Rayner, *Journal of the Institution of Electrical Engineers*, (England) 1912, Volume 49, p. 53, who describes his bibliography as follows:

The references given below are to articles in periodical literature only. With few exceptions they deal with the physics of dielectrics from the point of view of energy loss and electric strength.

The first section includes papers dealing with theory and experiments of a laboratory nature.

The second deals with instruments, chiefly electrostatic voltmeters and wattmeters, suitable for measurements on high-voltage circuits.

The third section includes papers on atmospheric phenomena at high voltages at or above ordinary pressures, more especially such as describe experiments of engineering interest.

In the fourth section are references to similar experiments in oils.

The fifth section consists chiefly of papers dealing with the electric strength of materials and energy loss in insulation. Articles on cables are included which discuss insulation problems; but such as deal merely with capacity, inductance, etc., have been omitted.

The number of articles on the subject of porcelain and porcelain insulators has increased so much since the publication of Rayner's bibliography, that an additional Section, namely Section V, has been included on this subject in the present bibliography, changing the general section into Section VI.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Pacific Coast Convention, Vancouver B. C., August 8-11, 1922

The tentative program of the Vancouver Convention which was published in the July issue of the JOURNAL has been adopted in full and may now be considered the final program. As no changes whatever have been made, it is unnecessary to repeat it in this issue of the JOURNAL.

As has been stated before, it has been the aim of the committee in framing this program to offer a diversity of interest which will make the Convention both pleasant and profitable to all who attend. In addition to the technical papers listed, there will be found several addresses on live topics of engineering interest, and the stereopticon talk showing the relative types and proportions of various kinds of power plants is a new feature of our Conventions which it is believed will prove of great interest.

Vancouver contains excellent hotels, parks, attractive drives, bathing beaches, etc., and its position as the principal Western port of Canada makes it especially attractive to visitors. It is confidently expected that a large representation from the membership of the Western states will be found in attendance at this Convention.

The Niagara Falls Convention

JUNE 26-30

The 38th Annual Convention of the A. I. E. E., held at Niagara Falls, June 26-30, was a pronounced success and has the distinction of being the best attended summer convention the Institute has ever held with the exception of one which was held in a large city. The attendance was so large that the capacity of the convention hotel and meeting rooms was severely taxed. The technical sessions were also unusually well attended. The social and entertainment features, games and sports which were arranged by the Convention committee and which were greatly enjoyed, supplemented a rather full technical program, so that almost every available moment was scheduled for some item of business or pleasure.

The total registration of members and guests was 953, including more than 125 ladies. Thirty-one states, Canada, Mexico, Cuba, Great Britain, France, Japan and India were represented.

One of the pleasant features of the Convention was the attendance of delegates from national societies in other countries. Mr. A. P. M. Fleming represented the Institution of Electrical Engineers of Great Britain and the British National Committee of International Electrotechnical Commission. Messieurs P. Charpentier and Jean Canivet represented the French National Committee of the I. E. C. Messrs. Walter J. Francis, H. G. Acres and Brigadier-General C. H. Mitchell represented the Engineering Institute of Canada.

The Board of Directors of the Institute held its regular June meeting on Thursday afternoon, June 29, as referred to elsewhere in this issue.

Committee meetings were held during the Convention by the Sectional Committee on Rating of Electrical Machinery, the Electrical Machinery Committee, and the Cable Research Subcommittee of the Transmission & Distribution Committee. Numerous informal conferences were also held by members of other committees of the Institute.

The Past-Presidents in attendance met with President McClellan and President-elect Jewett for luncheon on Wednesday, July 28. This gathering afforded a much enjoyed opportunity to discuss matters of interest relating to the policies of the Institute.

Every hospitality was offered the Convention visitors by local clubs and other organizations, and the Board of Directors at its meeting during the Convention passed the following resolutions:

RESOLVED: That the Board of Directors of the American Institute of Electrical Engineers, representing the membership at large, and more especially the members and guests in attendance at the Annual Convention at Niagara Falls, Ontario, June 26-30, 1922, hereby expresses its hearty appreciation of the effective services of the local members of the Convention Committee consisting of Messrs. R. F. Ewart, *Chairman*, H. G. Acres, W. P. Dobson, L. E. Imlay and J. Allen Johnson in making and carrying out with gratifying success the arrangements for the comfort and entertainment of the members and guests of the Institute attending the 1922 Annual Convention.

RESOLVED: That the Board of Directors of the American Institute of Electrical Engineers, representing the membership at large, and more especially the members and guests in attendance at the Annual Convention at Niagara Falls, Ontario, June 26-30, 1922, hereby expresses its hearty appreciation to

Hydro-Electric Power Commission of Ontario
Niagara Falls Power Company
Ladies' Entertainment Committee
Local Members of the Institute
Members of Niagara Peninsula Branch of Engineering Institute of Canada
Niagara Falls Country Club

for the many courtesies extended by them to the members and guests in attendance at the 1922 Annual Convention.

While the convention was officially opened on Tuesday, the Section Delegates' Conferences were held on Monday, an account of which is given below.

TUESDAY MORNING

President McClellan called the Convention to order and introduced Mr. A. Munro Grier, President of the Canadian Niagara Power Co. who delivered an address of welcome, to which President McClellan responded.

Mr. A. P. M. Fleming the next speaker brought felicitations from the Institution of Electrical Engineers of Great Britain, the British National Committee of the International Electrotechnical Commission and the British Electrical Standards Association and its Rating Panels. President-elect Jewett also

greeted the members and their friends. Mr. F. R. Ewart, Chairman of the Convention Committee, outlined the program of social events. The meeting then divided into two sessions.

SESSION I

Mr. F. W. Peek, Jr., acted as Chairman of Session I and called for presentation of the paper *The Two-Stage Current Transformer*, by H. B. Brooks and F. C. Holtz. This was discussed by James R. Craighead and P. A. Borden, with reply by Mr. Holtz.

The next paper was *Three Thousand Tests on the Dielectric Strength of Liquid Insulation*, by J. L. R. Hayden and W. N. Eddy, and was discussed by C. E. Skinner, W. A. Del Mar, E. D. Clarke, J. B. Whitehead, W. D. A. Peaslee, O. D. Wood, J. E. Schrader, F. W. Peek, Jr., and C. P. Steinmetz.

The third paper *Control of Gaseous Conduction*, by V. Bush and C. G. Smith, was abstracted by Mr. Bush and discussed by C. P. Steinmetz, J. B. Whitehead, W. H. Pratt and J. E. Schrader. Mr. Bush made closure.

The last paper of the session, *Determination of Temperature of Electrical Apparatus and Cables in Service*, by E. J. Rutan, was presented by the author and discussed by E. S. Lee, with closure by Mr. Rutan.

SESSION II

Mr. R. F. Schuchardt presided as Chairman of Session II and the following papers were presented.

The Economics of Direct-Current Railway Distribution (with particular reference to the Automatic Substation), by L. P. Crecelius and V. B. Phillips; discussed by Victor E. Thelin, D. W. Roper, W. E. Bryan (written), M. J. Lowenberg and E. R. Shepard (written).

Light Without Glare, by Ward Harrison, and was discussed by S. E. Doane, F. C. Caldwell and C. F. Scott.

Philadelphia-Pittsburgh Section of the New York-Chicago Cable, by James J. Pilliod, and was discussed by S. P. Grace.

In the absence of the author the paper on *A Method of Determining Resultant Input from Individual Duty Cycles and of Determining Temperature Rating*, by Bassett Jones, was presented by title and was discussed by V. Karapetoff.

TUESDAY AFTERNOON

Mr. B. A. Behrend acted as Chairman at the session Tuesday afternoon, which was devoted to four papers in relation to the Queenston hydroelectric plant. These papers were presented by the authors as follows:

Queenston-Chippewa Development of the Hydro-Electric Power Commission of Ontario, by F. A. Gaby.

Description of the 45,000-kv-a. Queenston Generators, by B. L. Barnes and F. Bowness.

Design of 45,000-kv-a. Generators, Queenston Plant, by R. A. McCarty.

Features of Main Power House Transformers for Queenston Plant, by C. A. Price.

The discussion which followed was by B. T. McCormick, W. J. Foster, O. D. Wood, W. M. Dann, R. B. Williamson and F. D. Newbury.

TUESDAY EVENING

Prior to the President's reception, which was held on Tuesday evening, President McClellan made a brief address in regard to the functions of the Institute and its opportunities for new development.

WEDNESDAY MORNING

The technical session on Wednesday morning was called to order by President McClellan and prior to the presentation of the papers for the session Mr. A. P. M. Fleming of England outlined the British practise in regard to rating and the heat limits of insulation. Mr. J. Canivet outlined the practise in France and also presented in abstract a paper by Guido Semenza in regard to the Italian practise. Mr. Isono of Japan also spoke briefly. The following papers were then presented:

Questions Relating to Standards of Rating, by F. D. Newbury.

Probable Values of Conventional Allowance for A-C. Generator Stator Windings, by F. D. Newbury.

Temperature Limits in Large Machines, by P. Torchio.

These were discussed by W. J. Foster, R. F. Schuchardt, Louis T. Robinson, R. B. Williamson, C. E. Skinner, F. W. Peek, Jr., H. L. Wallau, H. R. Woodrow, H. G. Reist, H. M. Hobart, B. A. Behrend, James Lyman, Wm. McClellan and W. F. Dawson. Closure by Messrs. Newbury and Torchio.

The next paper, *Higher Steam Pressures or Pulverized Coal?* by F. A. Scheffler, was abstracted by the author and discussed by Philip Torchio.

WEDNESDAY AFTERNOON

Wednesday afternoon was set apart for the inspection trip to the hydroelectric plant of the Queenston-Chippewa Development at Queenston and a large party of members and guests visited the station at this time, where they were conducted through the plant by guides who explained the various features of the installation. The entire afternoon was devoted to this inspection. The principal features of this plant have already been described in the four papers mentioned above.

WEDNESDAY EVENING

Mr. J. L. Harper gave an interesting lecture on Niagara Falls Plants, in which he outlined the historical development of the various power plants at Niagara Falls. The lecture was copiously illustrated with stereopticon views and was enjoyed by an audience which filled the lecture hall to capacity.

THURSDAY MORNING

The technical session on Thursday morning was presided over by Mr. W. A. Del Mar and was devoted to a group of seven papers, all in regard to the rating of cables in relation to voltage. These papers were presented by the authors as follows:

Rating of Cables in Relation to Voltage—Summarized History, by the Subcommittee on Wires and Cables of the Standards Committee.

Dielectric Losses and Stresses in Relation to Cable Failures, by D. W. Roper.

On the Minimum Stress Theory of Cable Breakdowns, by D. M. Simons.

Effect of the Composite Structure of Impregnated Paper Insulation on Its Electric Properties, by W. A. Del Mar and C. F. Hanson.

Potential Gradient in Cables, by W. I. Middleton and E. W. Davis.

Corona in Air Spaces in a Dielectric, by J. E. Schrader.

Action and Effect of Moisture in a Dielectric Field, by Delafield Du Bois.

Rating of Cables in Relation to Voltage—Bibliography on Dielectrics, by D. M. Simons.

This group of papers was discussed by E. B. Meyer, F. W. Peek, Jr., C. F. Scott, C. F. Proos (Delft, Holland), Philip Torchio, Henry W. Fisher (Communicated), A. W. Atkinson, A. Karapetoff, N. L. Morgan, B. Wilbourn (England), John B. Whitehead, W. C. Hayman, Wm. H. Cole, G. B. Shanklin and C. P. Steinmetz, with closure by the authors.

THURSDAY EVENING

President McClellan occupied the chair at the Thursday evening session, which was devoted to the subject of "Engineering Education." The following group of papers was presented by the authors:

Some Suggestions for Possible Improvements in Methods of Engineering Education, by B. G. Lamme.

Education, by S. E. Doane.

Principles of Engineering Education, by P. Torchio.

Better Preparation of Students for Railway Work, by I. C. Forshee.

Training for Character, by A. M. Dudley.

Some Suggestions Concerning the College Education of an Engineer, by Carl Hering.

These papers were discussed by Charles S. Howe, L. A. Ferguson (communicated), Farley Osgood, L. A. Doggett, J. B. Whitehead, W. T. Ryan, C. F. Scott, C. B. Hoffman, Edward Bennett, C. F. Harding, H. T. Plumb, W. P. Lovell, W. B. Hartshorne, V. Karapetoff, C. A. Adams, W. I. Slichter, L. H. Rittenhouse and J. E. Kershner.

FRIDAY MORNING

The final technical session of the Convention was called to order Friday morning, with Mr. H. R. Woodrow in the chair. Three papers in regard to the Baltimore oil circuit-breaker tests were abstracted by the authors as follows:

Baltimore Oil Circuit Breaker Tests, by H. C. Louis.

Tests on General Electric Oil Circuit Breakers at Baltimore, by J. D. Hilliard.

Tests on Westinghouse Oil Circuit Breakers at Baltimore, by J. B. MacNeill.

These papers were discussed by B. G. Jamieson, A. A. Meyer, H. L. Wallau, A. H. Hull, A. H. Sweetman, A. F. Bang, E. R. Stauffacher, F. C. Hanker, H. H. Dewey and M. J. Lowenberg.

The final paper on the program, *Transmission Line Relay Protection—II*, by E. A. Hester, O. C. Traver, R. N. Conwell and L. N. Crichton was then presented and was discussed by E. R. Stauffacher, A. Bailey, P. Ackerman, E. M. Wood, W. H. Cole, O. C. Traver, E. P. Peck, H. T. Plumb, L. N. Crichton and A. H. Sweetman.

ENTERTAINMENT

The entertainment features of the Convention were especially attractive and exceedingly enjoyable to all who participated. The various events had been carefully planned by the Convention Committee which was very ably assisted by a Ladies' Entertainment Committee, of which Mrs. S. K. Colby was Chairman.

Monday Afternoon, June 26th

Tea was served at the Hotel by a committee of ladies.

Tuesday Afternoon, June 27th

About 100 ladies were entertained at a tea given by Mrs. I. R. Edmands, at her residence in Niagara Falls N. Y.

On Tuesday evening several hundred members and guests attended the President's Reception which was followed by dancing until a late hour.

Wednesday, June 28th

The ladies present were taken on a motor trip to Niagara-on-the-Lake, tea being served at the Queens Royal Hotel.

Thursday, June 29th

About 100 ladies participated in the Gorge Route Trip, thus affording an opportunity to see most of the attractive features of the Falls and the Niagara River Gorge.

In the afternoon, one of the principal features was a bridge party, in which more than 50 ladies participated, the first prizes being won by Mrs. A. F. Riggs, Mrs. F. G. Boyce and Mrs. Wm. A. Warren and the consolation prizes by Mrs. W. I. Middleton, Mrs. S. D. Sprong and Mrs. H. B. Scharnberg.

A complimentary music recital was given by Professor V. Karapetoff of Cornell University assisted by Miss Victoria Tuttle, late Thursday afternoon, and was one of the most enjoyable events of the Convention, the large ballroom of the hotel being filled to capacity.

Friday, June 30th

Most of the members and guests who were not obliged to leave early were taken by motor to the Niagara Falls Country Club, where there was a putting contest for the ladies, the fortunate winners being Mrs. P. B. Yates, Mrs. E. Worthington and Mrs. C. F. Harding.

A highly appreciated musical program followed, through the kindness of Mrs. L. E. Imlay and Miss Victoria Tuttle.

Late in the afternoon tea was served on the club veranda, after which the various prizes for tennis and golf were presented.

TENNIS

Tennis tournaments were conducted in both singles and doubles, the finals being played on Friday afternoon. The men's singles were won by Mr. G. A. Sawin; the runner-up was Mr. Jean Canivet. The doubles were won by Messrs. G. A. Sawin and H. R. Summerhayes, the running-up team being Messrs. Canivet, of France, and John Murphy, of Ottawa.

GOLF

The golf contests were carried on during the week, the finals being played on Friday afternoon, prizes for the various events being awarded as follows:

First—Mr. P. H. Chase, Philadelphia
Runner-up, Mr. A. H. Sweetman
Second flight—Mr. H. D. Randall
Runner-up, Mr. G. B. Shanklin
Consolation Round—Professor C. A. Adams
Runner-up, Mr. R. O. Bentley
Lowest gross score—J. D. Lyon
Lowest net score in the qualifying round—Mr. Farley Osgood.

Mr. Chase's victory entitles him to have his name inscribed on the handsome Mershon trophy which will become the property of the person who wins the golf tournaments at two Institute Conventions. It has previously been won by Messrs. A. M. Schoen, of Atlanta; J. C. Mock, of Detroit; E. W. Allen, of Chicago, L. F. Deming, of Philadelphia; A. A. Brown, of New York, and Howard Maxwell of Schenectady.

Saturday, July 1st

Through the courtesey of the Toronto members, a trip to Toronto was arranged and was participated in on Saturday, about 65 members and guests leaving Lewiston by steamer in the morning. Luncheon was served at the Royal Canadian Yacht Club, at which Messrs. Berresford, Scott, and Adams each spoke briefly expressing their gratification over the convention in general and the hospitality of the Toronto members on the post-convention trip. They also referred fittingly to the close association between the peoples on the two sides of the border. After luncheon, the party was taken for an automobile trip through the city during which the principal points of interest were visited.

SECTION DELEGATES' CONFERENCES

As provided in the Constitution, conferences of Section delegates are held each year at the Annual Convention, under the auspices of the Sections Committee. This year a new plan was adopted, namely, that of devoting a whole day, prior to the beginning of the regular sessions of the convention, to the Section delegates' meetings, thus enabling the delegates to complete their program and be free to participate in the technical sessions and other events of the convention, which began the following morning.

The conferences were opened on Monday morning, June 26, and, with an intermission for luncheon, continued until late in the afternoon.

The delegates in attendance at these conferences were:

Section	*Delegate*
Akron	D. C. Hopper
Atlanta	A. M. Schoen
Baltimore	Frank T. Leilich
Boston	W. R. McCann
Chicago	M. M. Fowler
Cincinnati	J. D. Lyon
Cleveland	I. H. Van Horn
Columbus	F. C. Caldwell
Connecticut	Charles F. Scott
Denver	B. C. J. Wheatlake
Detroit-Ann Arbor	F. L. Snyder

Section	*Delegate*
Erie	C. H. Schum
Fort Wayne	R. H. Chadwick
Ithaca	R. F. Chamberlain
Kansas City	J. W. Wopat
Lehigh Valley	J. L. Beaver
Los Angeles	H. H. Cox
Lynn	F. J. Rudd
Madison	C. B. Hayden
Milwaukee	F. J. Mayer
Minnesota	W. T. Ryan
New York	H. A. Pratt
Philadelphia	P. H. Chase
Pittsburgh	H. W. Smith
Pittsfield	I. H. Sclater
Portland, Ore	D. W. Proebstel
Providence	W. W. Broadbent
Rochester	Sydney Alling
St. Louis	C. C. Robinson
San Francisco	W. P. L'Hommedieu
Schenectady	S. H. Blake
Seattle	E. S. Code
Spokane	L. J. Pospisil
Toronto	W. P. Dobson
Urbana	E. H. Waldo
Utah	H. T. Plumb
Vancouver	J. R. Read
Washington	A. R. Cheyney
Worcester	G. M. Hardy

Past-President A. W. Berresford, Chairman of the Sections Committee presided. Others present included President William McClellan, President-elect Frank B. Jewett, Secretary F. L. Hutchinson, and Messrs. E. E. F. Creighton (Chairman) and L. W. W. Morrow of the Meetings and Papers Committee. A number of other present and past officers and officers-elect of the Institute and of the various Sections were present and participated in the discussions.

Prior to the meeting all the Sections had been communicated with by the Program Committee and requested to suggest subjects for discussion at the conference. This committee, consisting of Messrs. F. J. Mayer (Chairman), Calvert Townley, and J. Lloyd Wayne, had prepared, and issued in advance, a program of the topics to be discussed; so that each delegate had an opportunity to ascertain the views of the members of his Section prior to the meeting.

The subjects thus officially suggested and placed upon the docket for discussion included the following:

(a) Should there be another grade of membership created by dividing the present group of Associates into "Junior Members" and "Associates"?

(b) Should Sec. 61 of the By-laws, which provides for no action which "may purport to represent the policy or organization of the Institute, or of any Section, shall be published without the approval of the Board of Directors," be modified by the deletion of the clause "or of any Section"?

(c) Should the present basis of financial support of Sections be modified in order to furnish greater support to smaller Sections, with a corresponding decrease in the appropriation for the larger Sections?

(d) Should each Section be left free to determine in what manner, and for what purposes, it may most usefully expend its appropriation? (The present rulings prohibit any portion being expended for social activities).

(e) Should there be an annual meeting in each geographical division of the Institute, under the auspices of the Sections within the district?

(f) Should the Executive Committee of each geographical district hold at least one meeting annually, and if so, how should the expenses be met?

(g) What is the delegates' preference in regard to the time of holding the annual meeting of Section delegates?

(h) General discussion of matters of mutual interest to the Sections and the Meetings and Papers Committee.

Prior to taking up the program outlined above, the Chairman presented President McClellan, who made a brief address in which he emphasized the importance and great value of the work of the Institute Sections. President-elect Jewett was then presented and made a brief address, pledging support of the work of the Sections and careful consideration by the Directors of all suggestions and recommendations made by the delegates.

All the topics listed were taken up and discussed at length. Briefly, some of the actions were:

(a) to recommend that no additional grade of membership be established at present;

(b) to recommend that Sec. 61 of the By-laws be modified in order to leave Sections free to express their views upon matters relating to the policy of their respective Sections;

(c) to recommend that the basis of support for Sections in future be $175 for each Section, irrespective of the number of members, plus $1 per member within the Section territory;

(d) to recommend that the Sections be left free to expend their appropriations as they deem best, but to report on the expenditures to the Secretary of the Institute for the information of the Finance Committee;

(e) voted that no plan be recommended at present in regard to an annual meeting in each geographical district;

(f) voted that meetings of the Executive Committee of each district be not made mandatory;

(g) voted unanimously to recommend that the practise at this convention be followed, namely, to hold the meetings of the Section delegates on the day prior to the beginning of the regular Annual Convention of the Institute.

The discussion regarding meetings brought out many points regarding the present practises of the various Sections and of the Meetings and Papers Committee in preparing programs and otherwise arranging for meetings.

The entire discussion was reported stenographically and an abstract of all the essential features will be prepared and printed in pamphlet form for distribution to the delegates and the officers of all Sections and of the Institute. It will also be available to any other members who are interested, upon application to the Secretary at Institute headquarters, New York.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at the Clifton, Niagara Falls, Ontario, on Thursday, June 29, 1922.

There were present: President William McClellan, New York; Past-President A. W. Berresford, Milwaukee; Vice-Presidents W. A. Del Mar, New York, J. C. Parker, Brooklyn, N. Y., N. W. Storer, Pittsburgh, C. G. Adsit, Atlanta; Managers W. I. Slichter, L. F. Morehouse, New York, F. D. Newbury, A. G. Pierce, Pittsburgh, L. E. Imlay, Niagara Falls, James F. Lincoln, Cleveland, R. B. Williamson, Milwaukee; Secretary F. L. Hutchinson, New York. Also present by invitation: Officers-elect Frank B. Jewett, New York, R. F. Schuchardt, Chicago, H. T. Plumb, Salt Lake City, H. M. Hobart, Schenectady, Ernest Lunn, Chicago.

Approval by the Finance Committee of monthly bills amounting to $17,054.69 was ratified.

The Secretary reported over 1000 members delinquent in the payment of dues for the past year, ending April 30, 1922, as compared with about 630 at the same time last year. The Board directed that the usual efforts be continued to collect these dues through the Secretary's office and by bringing the lists to the attention of the Section officers concerned.

A report of a meeting of the Board of examiners held June 23 was presented and the actions taken at that meeting relative to applications for election and transfer were approved. Upon the recommendation of the Board of Examiners the following action

was taken upon pending applications: 138 Students were ordered enrolled; 273 applicants were elected to the grade of Associate; 28 applicants were elected to the grade of Member; 3 applicants were elected to the grade of Fellow; 32 applicants were transferred to the grade of Member; 9 applicants were transferred to the grade of Fellow.

Petitions for authority to organize Institute Sections at Springfield, Mass., and the City of Mexico, were presented and granted.

A communication from the Standards Committee was presented, submitting revisions of and additions to the A. I. E. E. Standards, and recommending that a new edition of the rules, embodying all these changes, be issued immediately, to be known as the 1922 edition; and the Board voted to approve the revisions and additions as submitted, and to authorize the publication of a 1922 edition of the A. I. E. E. Standards.

The Secretary reported that by action of the American Engineering Council of the Federated American Engineering Societies, the employment Service, which had been carried on under the auspices of the Federation during the past year or more, would be returned to the jurisdiction of the four Founder Societies as of July 1, with a corresponding financial adjustment so that an equitable sum will be rebated to the four Founder Societies commencing July 1. Upon the recommendation of the Secretary the following resolution was adopted: That the Secretary be directed to continue the employment service practically as rendered for several years past to the membership of this Institute, and that he be authorized to coordinate this service with the employment activities of the other engineering societies, through a joint organization or otherwise as may be found feasible.

The President made a statement relative to the increase in the number and extent of the various Institute activities, and the desirability of increasing the administrative staff, also to a resolution adopted at a meeting of the Section Delegates on June 26, requesting an extension of the service from Institute headquarters; and the following resolution was adopted: That a committee of three be appointed to report to the Board not later than the meeting of October 1922, on the additions necessary to the administrative organization of the Institute, and to make specific recommendations for early action.

A resolution was unanimously adopted expressing the appreciation of the Board of the effective manner in which President McClellan has served the Institute during the past year. President McClellan responded briefly, expressing his appreciation of the opportunity of association with the members of the Board.

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

Automotive Engineers Meeting in October

A national meeting of the Society of Automotive Engineers will be held in Detroit October 26-27 for the purpose of discussing problems of automotive production. The meeting is to be known as the S. A. E. Automotive Production Meeting.

Papers treating current production problems in a simple and practical way will be read and fully discussed in morning meetings on each of the two days. The afternoons will be devoted to factory inspection trips especially arranged for the purpose of viewing new and advanced production methods. The principal object of this meeting is the promotion of an interchange of experience between practical factory men on automotive production problems which are troubling them in their daily work. An S. A. E. Production Dinner will be held Thursday evening October 26.

Annual Convention, Iron and Steel Electrical Engineers

The sixteenth Annual Convention of the Association of Iron and Steel Electrical Engineers will be held in Cleveland, Ohio, September 11-15, 1922.

A tentative list of papers to be presented shows a large proportion of them will be devoted to practical information in regard to the electrical applications in iron and steel mills. In addition to the technical sessions, there is to be an attractive exhibition of apparatus of particular interest to steel mill engineers.

Safety Congress to Meet in Detroit

The eleventh Annual Safety Congress of the National Safety Council will meet in Detroit, August 28—September 1, at the Cass Technical High School.

The program which has been issued is an extensive one, and includes among other items details of engineering section meetings, at which there will be discussed matters of importance to engineers generally, as well as to those specializing in accident prevention.

The National Safety Council extends a cordial invitation to all of the membership of the A. I. E. E. to attend this Congress and the engineering meetings in particular.

International Engineering Congress in Brazil

An International Congress of Engineering, the first of its kind in Latin America, is to be held under the auspices of the Brazilian government at Rio de Janeiro, September 7-30, in connection with the opening of the Brazilian International Exposition and other features of the celebration of the first centennial of Brazilian independence. The Exposition will be opened on September 7, 1922, the Brazilian Independence Day, and will last until March 31, 1923.

The Club de Engenharia of Rio de Janeiro, officially charged with organizing the International Congress of Engineering, has extended a cordial invitation to the American Institute of Electrical Engineers, through the Brazilian Embassy at Washington, to participate in the Congress.

The work of the Congress will be organized under eight sections: (1) Transportation; (2) Iron and Steel; (3) Fuel; (4) Water Power; (5) Public Works in general; (6) River and Sea Ports; (7) Industrial and Agricultural Machinery; (8) Statistical Methods at Ports and Railroads.

Some of the sessions of the International Congress of Engineering will be held together with the Second South American Congress of Railroads. Some of the excursions in Brazil will also be made by the members of that Congress.

Members of the A. I. E. E. who expect to visit Brazil in September are requested to notify the Secretary of the Institute promptly.

Senator Marconi Receives the John Fritz Medal

Before the largest gathering of engineers that ever witnessed the presentation of the John Fritz Medal, Senator Guglielmo Marconi, the great Italian engineer, Honorary Member of the A. I. E. E., received this signal honor for 1923 on the evening of July 6, 1922 at the Engineering Societies' Building, New York. Previous to the presentation ceremonies, the John Fritz Medal Board gave a dinner in honor of Senator Marconi at the Engineers' Club.

At the presentation ceremonies, Comfort A. Adams, chairman of the Medal Board, presided and read messages from medallists, distinguished engineers and public men of America and Europe.

The speakers, all of whom eulogizing Marconi, dwelt upon different aspects of his life work and its meaning to human society, included James R. Sheffield, prominent lawyer of New York and for many years counsel to Marconi; Dr. Michael I. Pupin, professor of electro-mechanics at Columbia; and Dr. Elihu Thomson, John Fritz Medallist of 1916, who presented the medal to Marconi.

Senator Marconi in responding to the address of presentation voiced the hope that he had been instrumental in advancing concord among the peoples of the earth.

Prof. Adams in his opening speech described the origin and purpose of the medal, saying that since the first award was made to John Fritz, great engineer and metallurgist, on his 80th birthday in 1902, seventeen annual awards had been made "to men of the very highest distinction in the great profession of engineering." Prof. Adams then called attention to the presence of four medallists; Dr. Elihu Thomson, medalist of 1916, inventor, and dean of electrical engineering; Dr. J. Waldo Smith, who solved the N. Y. water supply problem; General George W. Goethals, builder of the Panama Canal; Dr. Orville Wright, who with his brother developed the first successful airplane.

James R. Sheffield eloquently pictured the personal side of Marconi, outlining his early life, his struggles and ultimate triumph. Prof. Pupin summarized the achievements which describe the power of the new science of electrical transmission, saying "No poet or philosopher of today would be sufficiently daring to predict with any degree of accuracy the future expansion of this new science." Messages were read from Vice President Coolidge, Herbert Hoover, Thomas Edison, Guido Sabetta, Charge d'Affaires of Italy, at Washington; Sir Robert Hadfield of London and Eugene Schneider of Paris, both medalists.

American Engineering Council

COMMITTEE ON PROCEDURE MEETS

Federated American Engineering Societies' Committee on Procedure met in New York City on Friday, July 14. Both the afternoon and evening sessions were fully attended.

The invitation to send representatives to the Pan Pacific Commercial Conference in September was accepted. Appointment of a representative to attend the Engineering Congress in Rio de Janeiro in September was authorized. The President was also authorized to cooperate with the necessary authorities in appointing a committee of engineers to make a trip to China in the near future to form personal contacts and encourage friendly relations.

The return of patents from the Chemical Foundation to the Alien Property Custodian was considered by the Committee following which a resolution was addressed to the President requesting that action be delayed until representatives of the chemists, chemical engineers and manufacturers, and others could be heard. It furthermore implored that nothing be done which would in any way tend toward the ultimate return, to former owners, of patents and other property lawfully sequestered and sold to Americans.

Revision of the Mining Laws proposed in H. R. 7736 was approved by the Committee and Council directed to use its influence in furthering the passage of the bill subject to committee amendments. The Executive Secretary is in communication with the Chairman of the Mines and Mining Committee on behalf of this legislation.

The Committee approved the opinion that the following bills were not within the scope covered by the activities of the American Engineering Council; the Bacharach bill affecting public utilities companies, the Merchant Marine bill, the Trade Associations regulating bill and the Ship Subsidy bill. It approved the principle of the hydraulic laboratory bill but recommended that no special exertion be made in favor of it until a special committee of the Boston Society of Civil Engineers, to be appointed at the request of Council, could review the whole subject and advise the Executive Board.

The Executive Secretary reported that the Engineers and Architects Club of Louisville, Kentucky, had applied for membership in the Federation.

The next meeting of the Executive Board is to be held in Boston, Sept. 8 and 9.

BASIS OF WATER POWER DEPRECIATION

Before the depreciation regulation promulgated in connection with the Water Power Act can be altered as requested by the National Electric Light Association, the Act itself will have to be amended. The Federal Power Commission, at its meeting in July, announced that after an exhaustive consideration such a conclusion has been reached. The decision ends uncertainty in regard to this important matter and follows closely after a letter from the Federated American Engineering Societies calling the attention of the Secretary of War to the delay in reaching a conclusion in the matter. The Commission approved a suggestion of O. C. Merrill, its Executive Secretary, that it be optional with licensees whether they account for depreciation on the straight-line basis or on the sinking-fund basis, pending any effort that may be made to amend the Act. Mr. Merrill was authorized to confer with the Water Power Development Committee of the National Electric Light Association, to work out proposals for securing such degree of flexibility in the depreciation charges as will be helpful to the licensee. The ruling of the Commission on several recent declarations of intention indicates a liberal policy in allowing the construction of dams in navigable streams where the commerce is not important.

Addresses Wanted

1. Eugene A. Baerer, Box 253, Kenvil, N. J.
2.—B. R. Batcher, 179 Marcy Ave., Brooklyn, N. Y.
3.—G. E. Bliziotis, 284 Market Street, Newark, N. J.
4.—Ricardo S. Bravo, Jr., 621 South Flores St., San Antonio, Texas.
5.—E. J. Condon, Jr., Minn. Electric Light & Power Co., Elks Bldg., Bemidji, Minn.
6.—O. A. Darnell, 409 East 5th Street, Los Angeles, Calif.
7.—John F. Donohue, 45 2nd Street, Newark, N. J.
8.—Edward F. Doyle, National Conduit & Cable Co., Hastings-on-the-Hudson N. Y.
9.—M. V. Eardley, P. O. Box 664, Long Beach, Calif.
10.—Earl V. Edkins, 5827 Trinity Place, W. Philadelphia, Pa.
11.—J. Allen Fitz, 19 Fort Green Place, Brooklyn, N. Y.
12.—Frank Hempton, P. O. Box 431, Gallup, New Mexico.
13.—Arthur S. Howard, 2735 South Alder St., Philadelphia, Pa.
14.—Carl Irving, Box 675, Porterville, Calif.
15.—Hardev S. Kahai, P. O. Box, Kapargaon Dist., Ahmednagar, Deccan, India.
16.—J. M. Kite, Guaranty Co., of New York, 140 Broadway, New York, N. Y.
17.—Gody Krusy, 16 Elizabeth Ave., Newark, N. J.
18.—Wen Siang Lu, Y. M. C. A., Lynn, Mass.
19.—McCauley, New Brunswick Power Co., St. Johns N. B.
20.—H. F. Pippenger, 4647 Kenmore Ave., Chicago, Ill.
21.—J. Hubert Shanhan, 537 Morris Ave., Elizabeth, N. J.
22.—T. V. Tillinghast, Plano Toy Co., Plano, Ill.
23.—C. H. Underwood, Room 220 Ry. Equipment Dept., General Electric Co., Schenectady, N. Y.

American Engineering Standards Committee

NATIONAL ELECTRIC SAFETY CODE

The American Engineering Standards Committee has approved the National Electrical Safety Code of the Bureau of Standards which covers the generation, distribution and utilization of electricity for power light and communication.

In making public this decision, the Committee announces that there is now in process of formation a throughly representative sectional committee to consider any revisions of Part 2 of this Code, "Rules for the Installation and Maintenance of Overhead and Undergound Electrical Supply and Signal Lines", which may be deemed necessary by any of the interested parties. There are also being organized three sub-committees to take up the unification of crossing specifications under the three following heads: Signal lines crossing railways; power lines crossing railways; and power lines crossing signal lines.

It is believed that this action, together with the organization of the representative committees to take care of the revision of the Code and to prepare the crossing specifications, constitutes one of the most important steps yet taken in securing national uniformity in these matters.

ILLUMINATING ENGINEERING STANDARDS APPROVED

The Illuminating Engineering Nomenclature and Photometric Standards of the Illuminating Engineering Society 1918 edition, have been approved by the A. E. S. C. as "American Standard" with the substitution of six internationally agreed upon definitions for certain ones of the 1918 rules. The definitions which have been reworded are; luminous flux, luminous intensity, illumination, candle, lumen, and lux.

The special committee of the A. E. S. C. which examined the proposal submitted by the I. E. S. and which recommended approval of the nomenclature and photometric standards included representatives of the U. S. Bureau of Standards, the American Gas Association, the American Physical Society, the International Acetylene Association, the Optical Society of America, the American Institute of Electrical Engineers, the Illuminating Engineering Society, and the National Electric Light Association.

The new definitions to be substituted for existing text in Sections 3, 8, 9, 10, 12 and 13 of the Nomenclature and Standards Rules, Illuminating Engineering Society, 1918 Edition, are as follows:

Section 3. Luminous Flux is the rate of flow of radiant energy evaluated with reference to visual sensation. Although luminous flux must strictly be defined as above, it may be regarded for practical photometric purposes as an entity, since the rate of flow is for such purposes invariable.

Section 8. The Luminous Intensity of a point source in any direction is the flux per unit solid angle emitted by the source in that direction. (The flux from any source of dimensions which are negligibly small by comparison with the distance at which it is observed, may be treated as if it were emitted from a point.

Section 9. Illumination at any point of a surface is the luminous flux density at that point, or, when the illumination is uniform, the flux per unit of intercepting area.

Section 10. The unit of Luminous Intensity is the International Candle such as has resulted from international agreement between the three national standardizing laboratories* of France, Great Britain and the U. S. A. in 1909.

This unit has been conserved since then by means of incandescent electric lamps in the laboratories which continue (or remain) charged with its conservation.

Section 12. The Unit of Luminous Flux is the Lumen. It is equal to the flux emitted in a unit solid angle, by a uniform point source of one international candle.

*These laboratories are the Laboratoire Central d'Electricite, Paris, the National Physical Laboratory, Teddington, and the Bureau of Standards, Washington.

Section 13. The practical unit of illumination is the Lux. It is equal to one Lumen per square meter, or it is the illumination at the surface of a sphere of one meter radius due to a uniform point source of one international candle placed at its center.

As a consequence of certain recognized usages, the illumination can also be expressed by means of the following units:

Using the centimeter as the unit of length the unit of illumination is one lumen per square centimeter, and is called the Phot. Using the foot as the unit of length, the unit of illumination is one lumen per square foot, and is called the Foot-Candle.

PERSONAL MENTION

E. R. Shepard has moved from his office in Washington, D. C., to the Edison Building, Chicago, Ill., where he will continue his work as consulting engineer.

F. W. Carter, formerly with the Westinghouse Company, East Pittsburgh, Pa., is now President of the Louisville Frog & Switch Company, Louisville, Ky.

J. C. Foster has severed his connection with the Utica Gas & Electric Co., Utica, N. Y., and is now with the Adirondack Power & Light Corp., Amsterdam, N. Y.

Ernest Jones, formerly of Camaguey, Cuba, has been appointed Assistant Superintendent of the Butler District of the West Penn Power Company, Butler, Pa.

Francis H. Achard recently severed his connection with the Angus Co., Ltd., Calcutta, India, and has joined the Inspection Department of the Stone & Webster Engineering Corp., Pittsburgh, Pa.

N. E. Camp has resigned from the General Electric Company to become vice-president and chief engineer of the Roberts Engineering and Construction Co., Marysville, Cal., and Sacramento, Cal.

Trice M. Bell, formerly Assistant Instructor, Electrical Engineering Department, University of Illinois, is now connected with the Lighting Department of the General Electric Company, Schenectady, N. Y.

Arch Robison, who has been in Florida for the past year with the Southern Utilities Company, is now in charge of construction work being done for the Virginia Western Power Company at Ronceverte, West Va.

Lewis B. Newell, formerly General Manager of the Automatic Illuminated Advertising Corp., New York, has become associated with the Sales Department of Hoagland, Allum & Company, Inc., New York.

Henry H. Plum, formerly connected with the Electrical Division of the U. S. Reclamation Service in Denver, Colo., has been transferred to the Minidoka Project, Idaho, as assistant in charge of the project power system.

H. D. Shute, vice-president and general sales manager of the Westinghouse Electric & Manufacturing Company, has been elected a member of the board of directors of the Standard Underground Cable Co., Pittsburgh, Pa.

Roger B. Stevens, formerly electrical engineer, Consulting Board of the American Sugar Refining Company, New York, has opened an office at 51 East 42nd Street, New York, to engage in consulting and construction work for all classes of industry.

A. B. Saurman, has been elected vice-president of the Standard Underground Cable Company. He was formerly general sales manager of the company and will combine his duties as such with those of his new office.

Noel F. Harrison, of the Manitoba Power Company, Ltd., Winnipeg, Man., Canada, is on an extended visit to Ireland. His interest in peat-gas power will cause him to look into the possibilities of developing some of the immense bog areas in that country.

W. W. Simons, who until recently was connected with the Supply Department of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., is now affiliated with the Western Electric Company, General Telephone Supply Sales Department, New York.

Boyd Candlish has been appointed manager of the Detroit branch of Herbert Morris, Inc. He was formerly chief engineer of the Herbert Morris Crane & Hoist Company, Niagara Falls, Ont., and is still acting in a consulting capacity on the design of special hoisting motors, magnetic brakes and controllers for both companies.

George S. Parker, has resigned as instructor of Electrical Engineering at the University of Illinois, to become assistant professor of Electrical Engineering at the Syracuse University, Syracuse, N. Y. Professor Parker was attached to the Air Service of the U. S. Army for two years during the war and spent eighteen months of that time in France.

E. B. Phillips, who for the past two years has been instructor in electrical engineering at the United States Naval Academy, Annapolis, and at the Georgia Institute of Technology, Atlanta, Ga., has been appointed instructor in electrical engineering at the Carnegie Institute of Technology, Pittsburgh, Pa., and will begin his new duties September 1st.

Professor A. J. Wurtz, who has been on the staff of the Department of Electrical Engineering at the Carnegie Institute of Technology, Pittsburgh, is to retire next fall, and will devote all of his time to research work in electrical engineering for the Division of Cooperative Research. Professor Wurtz is the discoverer of the five-non-arcing metals, and has made many notable inventions during his career.

Charles R. Underhill, who for ten years was chief electrical and consulting engineer of the Acme Wire Company, has opened an office at 342 Madison Avenue, New York, as a consulting engineer. His experience also includes eight years with the Western Electric Co., New York, and four years with the Varley Duplex Magnet Company, Jersey City, N. J. and Providence, R. I. For 14 years Mr. Underhill was immediately associated with the Varley winding machines, products and processes.

Obituary

Jefferson E. Kershner, professor of physics and applied electricity, Franklin and Marshall College, Lancaster, Pennsylvania, died suddenly at Niagara Falls, Ontario, on Thursday evening, June 29, 1922.

Professor Kershner's death occurred during the recent Annual Convention of the American Institute of Electrical Engineers, immediately after the close of a technical session in which he had participated in a discussion on educational subjects.

Professor Kershner was born in Berks County, Pennsylvania, August 16, 1854. He was a graduate of Franklin and Marshall College, 1877, and later received the degree of PhD. at Yale. He became professor of mathematics and physics at Franklin and Marshall College in 1880, and has remained continuously with that institution until his death. He was also active as consulting engineer of the Edison Company at Lancaster. He became an Associate of the A. I. E. E. in 1902. Professor Kershner was unmarried.

David D. Faris, manager of the Marine Department of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, diedly suddenly of apoplexy in his office, Monday, July 10. He was born in Wheeling, West Va., and after graduating from grammar school he attended the Linsley Military Academy. Upon the completion of his studies there in 1896, he was employed in the Bellaire Steel Works, Bellaire, O., and at the outbreak of the Spanish-American War joined the army and went to the Philippines. Upon his discharge in 1899 he took a commercial course and worked for several firms until May 1904 when he became connected with the Westinghouse Machine Company, in charge of the Detroit and Indianapolis offices, which firm was absorbed by the Westinghouse Electric & Manufacturing Company in 1915, when Mr. Farris returned to East Pittsburgh and was made Assistant Manager of the Marine Department, which position he held until his promotion on July 1, 1922. He was an associate of the Society of Naval Architects and Marine Engineers, of the Society of Naval Engineers and of the American Institute of Electrical Engineers.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (JUNE 1-30, 1922)

Unless otherwise specified books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

Electric Power Systems.

By William T. Taylor. Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1922. (Pitman's technical primer series.) 107 pp., 6 x 4 in., cloth. $.85.

This little book is an extremely brief introductory statement of the main technical facts and principles governing modern practise in the larger electric power systems. General circuit conditions are considered; the most important methods and prob-

lems in generation, transmission and distribution practise are explained; and special attention is paid to system operation, to the various "system factors" used, and to the importance of keeping reliable operating records.

Electrical Engineering Testing.

By G. D. Aspinall Parr. Fourth edition. N. Y., E. P. Dutton & Co., 1922. (Directly-useful technical series.) 691 pp., illus., diagrs., 9 x 6 in., cloth. $8.

This is a systematic course of instruction in testing alternating and continuous current machinery and equipment, for use by students and by engineers engaged in practical work. The present edition has been considerably enlarged, chiefly by adding new tests, and rearranged so that tests of a like nature are together.

Elektrische Behandlung von Gasen.

Herausgegeben von Henri Silbermann. Leipzig, Dr. Max Jänecke, 1922. 348 pp., illus., diagrs., 8 x 6 in., paper. $3.20.

This work is a summary of information upon the effect of electric discharges upon gases, especially the atmosphere, as disclosed by an examination of the German patent records. The subjects discussed are the activation of oxygen (preparation of ozone), the separation of solid or liquid particles from gases (purification by dust and mist removal) and the double decomposition of reaction masses containing at least two elements (synthesis of nitric oxid, ammonia, cyanogen, etc.). The book is a convenient record of the present state of these arts.

Elements of Radio Telephony.

By William C. Ballard. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 132 pp., illus., plates, diagrs., 7 x 5 in., fabrikoid. $1.50.

This book gives a simple discussion of what happens when messages are sent and received by radio of the apparatus required to produce these effects, and of its method of operation. It also gives practical unbiased information for the experimenter who wishes to learn what apparatus is necessary to produce certain results. Being intended for non-technical readers, the use of mathematics is avoided almost entirely.

High Voltage Power Transformers.

By William T. Taylor. Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1922. (Pitman's technical primer series.) 117 pp., illus., diagrs., 6 x 4 in., cloth. $.85.

A general practical survey of the characteristics, construction, installation, operation and troubles of modern high voltage power transformers. Intended for station operators and general electric engineers and so does not treat problems of fundamental design, details of construction and similar topics which chiefly concern manufacturers.

Hydro-Electric Installations of India.

By Shiv Narayan. Poona, India, The Author, 1922. 302 pp., illus., 10 x 6 in., cloth, 9 rupees.

This book presents in popular form the principal facts concerning the hydroelectric plants and projects of India. It also explains the hydraulic and electrical principles involved, the general design and installation of plants and the economic factors to be considered. The work is intended to direct attention to the water power resources of the country and to serve as a guide to engineers and capitalists interested in the utilization of them.

On the Electro-Deposition of Iron.

By W. E. Hughes. Lond., H. M. Stationery Office, 1922. (Dept. of Scientific and Industrial Research. Bulletin No. 6.) 50 pp., plates, paper. 6s. 8½d.

Reports of the results of an extensive laboratory investigation of the structure of electro-deposited iron, together with the author's conclusions regarding the influence of various factors upon this structure. The effects of temperature, current density, and movement of the cathode or electrolyte are given special attention. The conclusion is reached that the general theories entertained in regard to the crystallization of other substances hold also for deposited metal and that the dominant factor governing structure is concentration.

Practical Wireless Telegraphy.

By Elmer E. Bucher. Revised edition. N. Y. and Lond., Wireless Press, 1921. 336 pp., illus., diagrs., 9 x 6 in., cloth. $2.25.

The author endeavors to give non-technical students and practical telegraphers an understanding of the working of modern commercial apparatus. Stress is laid upon the construction of apparatus and the methods of manipulating it, without attempting a complete account of the scientific principles underlying it.

Testing of Transformers and Alternating Current Machines.

By Charles F. Smith. Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1922. (Pitman's technical primer series.) 91 pp. illus., 7 x 4 in., cloth. $.85.

Gives in compact form an outline of the main principles underlying practise in making efficiency and output tests of alternating transformers, generators and motors for commercial purposes.

Past Section and Branch Meetings

PAST SECTION MEETINGS

Madison.—June 5, 1922, Womans Building. Election of officers as follows: Chairman, H. M. Crothers; Secretary, R. C. Walter. Attendance 15.

Milwaukee.—June 21, 1922, Milwaukee Athletic Club. Business meeting of the Engineers' Society of Milwaukee. Election of officers of Milwaukee Section A. I. E. E., as follows: Chairman, George G. Post; Secretary-Treasurer, F. A. Kartak. Employees of the Wisconsin Telephone Company gave a demonstration of Multi-Office Telephone Switchboard and Operating Methods using a new demonstration board which is the equivalent of the boards at two exchanges and at private homes. Attendance 125.

Minnesota.—June 19, 1922, Curtis Hotel, Minneapolis. Election of officers as follows: Chairman, Fred A. Otto; Secretary, H. W. Meyer. Subject: "The Muscle Shoals Project." Speaker: Professor Charles A. Mann, Ph. D., of the University of Minnesota. The meeting was held in conjunction with the Engineer's Club of Minneapolis. Dinner was served preceding the meeting. Attendance 106.

Philadelphia.—June 14, 1922, Howard McCall Field, Llanerch, Pa. Election of officers as follows: Chairman, E. B. Tuttle; Secretary-Treasurer, Ross B. Mateer. Addresses were made by Messrs. P. H. Chase, retiring Chairman, E. B. Tuttle, Chairman-elect, and Charles Penrose, Chairman-elect of the Philadelphia Section of the A. S. M. E. The afternoon and evening was in the nature of a field day, golf, tennis and baseball being principal events. An informal dinner followed the field events, with an attendance of 117.

Pittsburgh.—May 9, 1922, Science Hall, Carnegie Institute of Technology. Subject: "Electricity and Matter"—(a) The electron as a universal constituent of matter; (b) The arrangement of electrons in atoms; (c) Conditions for emission of electrons from atoms; (d) Emission of electrons from hot cathode; (e) General discussion of principles covering the application of electron emission to general engineering problems describing the kenotron, photron, dynatron and magnetron. Speaker: Dr. Saul Dushman, General Electric Company. Attendance 550.

June 13, 1922, Hotel Chatham. Election of officers as follows: Chairman, E. C. Stone; Secretary, O. Needham. Subject: "The Engineer as Business Man and Executive." Speaker: Mr. Ralph Rainsford, Chief Engineer of the Philadelphia Company. Light refreshments were served. Attendance 140.

Vancouver.—June 16, 1922, Board of Trade, Vancouver. Election of officers as follows: Chairman, T. H. Crosby; Secretary F. W. MacNeill; Executive Committee, Messrs. J. Muirhead, R. L. Hall, John R. Read. Attendance 15.

PAST BRANCH MEETINGS

Michigan Agricultural College.—June 6, 1922. Subject: "Community Morale." Speaker: Richard K. Orr, President, Wolverine Insurance Company. A three-reel film entitled "The Benefactor" was shown. Attendance 35.

Ohio State University.—May 17, 1922. An illustrated lecture on the "Electrification of the Chicago, Milwaukee & St. Paul Railway—Intimate Details of Construction and Operation" was given by Mr. T. J. Murray of the C. M. & St. P. Ry. Attendance 250.

University of Washington.—June 6, 1922. Election of officers as follows: Chairman, J. V. Wilson; Secretary, Allan W. Lundstrum. A banquet was given at the U. of W. Commons for the local Branch. The speakers of the evening were several of the past chairmen of the Branch and Dr. Magnusson, Dean of the College of Engineering. Attendance 31.

Employment Service Bulletin

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

MEN AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after a period of three months, during which period names and records will remain in the active files.

NOTE.—Notices for the JOURNAL ***should be addressed to EMPLOYMENT SERVICE, 33 West 39th Street, New York, N. Y.,*** *the employment clearing house of the National Societies of Civil, Mechanical, Mining and Electrical Engineers.*

Notices for the JOURNAL are not acknowledged by personal letter, but if received prior to the 16th of the month will appear in the issue of the following month.

All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case ***and forwarded to EMPLOYMENT SERVICE,*** *as above.*

Replies received by the bureau after the position to which they refer has been filled will not be forwarded, and will be held by the bureau for one month only.

OPPORTUNITIES

PHYSICIST OR ELECTRICAL ENGINEERS (2) for development and engineering work on vacuum and gas-filled electrical devices. Post-graduate degree desirable. Application in person, by appointment. Location, New York City. V-1390.

RADIO ENGINEER for large electrical manufacturing company. Should be technical college graduate in electrical engineering, with experience in experimental radio development problems involving both transmitting and receiving. None but high grade development engineers need apply. Application by letter stating age, education and experience. Salary not stated. Location, Pa. V-1402.

STEAM POWER ENGINEER, by large industrial organization, to work up general engineering and sales data on steam power apparatus. Mechanical engineering graduate with about ten years experience in central station work and problems of combustion and heat balance required. Application by letter stating age, education and experience. Salary not stated. Location, Pa. V-1434.

OPERATING SUPERINTENDENT for Electric Light and Power Public Utility Company. Electrical Engineering graduate preferred. Extensive experience in operation of steam plants and high voltage transmission lines, substations, distribution system and meter work necessary. Ability to handle men successfully essential. Application by letter stating fully as to education, experience, qualifications and salary desired. Location, W. Va. V-1435.

SUPERINTENDENT of Transmission and Distribution system desired by Public Utility Company to handle operation and maintenance of high voltage lines and substations up to 60,000 volts. Also 2300 and 4000 volt distribution system. At least 8-10 years experience necessary. Engineering education desirable but not necessary. Application by letter giving full particulars and references. Location, W. Va. V-1436.

INSTRUCTOR for Electric Utility Corporation. Technical man with teaching experience and knowledge of Central Station business to teach classes of new and old employees, in Engineering and Commercial branches. Application by letter. Send photograph and full particulars. Salary not stated. Location, Middle West. V-1439.

FACTORY SUPT. to take charge of manufacture of portable electrical measuring instruments. Business is small at present, but having been established for a number of years, is ripe for expansion. Must be thoroughly familiar with technical details of design of ammeters, voltmeters and wattmeters for use on both A-C. and D-C. Previous experience in manufacture of precision instruments although not absolutely required is highly desirable and all other factors being equal, preference will be given to such applicant. Superintendent will establish routine of manufacture and assembly, prepare standard specifications, giving limits, and in every way put business on organized engineering basis. In this connection, the engineer selected will be given carte blanche. Application by letter stating age, education and experience in detail. Salary reasonable and at stated time if capabilities of engineer have been demonstrated will be given opportunity to secure a substantial interest in corporation. Location, New York City. V-1446.

ASSOCIATE PROFESSOR of Electrical Engineering. Teaching experience and practical experience in electrical engineering work essential. Application by letter. Location, Southeast U. S. V-1479.

ELECTRICAL ENGINEERING GRADUATE with between 3 and 5 years experience on Valuation Public Utilities. In answering attach photograph and state date can report for duty. Application by letter. Salary not stated. Location, Middle West. V-1481.

ELECTRICIANS (2) capable of handling electrical instruction. Should be thoroughly familiar with practical work including conduit BX, knob, and tube work, motor installations, switchboard and small power station operation and understand sector repairing and storage battery work. Application by letter. Salary not stated. Location, East U. S. V-1482.

RECENT GRADUATES with degree in mechanical engineering for student engineering course offering valuable opportunity for experience in application of theory to practise. Men of pronounced mechanical and mathematical aptitude preferred. Application by letter or in person. Large manufacturing concern. Location, Mass. V-1501.

DESIGNING DRAFTSMAN with experience on mechanical end of electric elevators. Application by letter. Salary not stated. Location, N. Y. City. V-1511.

DESIGNER & INSTALLATION MAN on elevator construction. Must be familiar with all forms of electric elevator construction and be able to design and supervise installation. Application by letter. Salary not stated. Location, New York City. V-1529.

HYDRO ELECTRIC ENGINEER to design plant, select site, and construction. Application by letter. Location, New York State. V-1534.

ENGINEER to design and install high speed automatic devices. Application by letter. Location, New York City. V-1537.

ENGINEERS to work on design of controllers for elevators, cranes and hoisting machinery. Experience in design and application of control apparatus essential. Must have good knowledge of motor design and of hoist work both on direct and alternating current. Will pay a reasonable salary depending upon ability of man. Permanent position. Application by letter. Location, California. V-1553.

MAINTENANCE ENGINEER with chemical plant experience, preferably dye plant. Must be able to design and equip additions to plant. Graduate Engineer from well known college. Should have had G. E. or Westinghouse test course. Application by letter. Location, N. J. V-1562.

TECHNICALLY TRAINED YOUNG MEN (2 or 3), who are interested in getting into selling end of illuminating and electrical engineering and contracting. Prefer men with experience in estimating and selling, but might consider training an exceptionally ambitious young man in our line. Compensation on a commission basis with drawing account. Refined bearing, ability to present oneself, and adaptability, together with an ardent desire to learn all details of our work, are absolute essentials; as positions will be permanent. Application in person, by appointment. Location, Brooklyn, N. Y. V-1565.

YOUNG ELECTRICAL ENGINEER with electric signalling experience, estimating experience, etc., as estimators. Permanent position with future. Application in person. Location, New York City. V-1587.

ELECTRICAL DRAFTSMAN for circuit work. Permanent. Application in person. Location, New York City. V-1588.

ELECTRICAL ENGINEER for circuit analysis work, must know rate setting, method sheets, etc. Permanent with future. Application in person. Location, New York City. V-1589.

ELECTRICAL ENGINEER as technical investigator. Must be tactful, with good personality. Must know rate setting. Permanent.

Application in person. Location, New York City. V-1590.

PARTNER to start contracting business in electrical equipment of buildings and mechanical equipment of factories. Requires both investment (about $5000) and ability to obtain and close contracts. Application by letter. Salary, division of profits. Location, New York City. V-1594.

INSTRUCTOR in Electrical Engineering. Work mostly laboratory but prefer some experience with radio or telephony. Application by letter. Location, South. V-1596.

BRANCH MANAGER, capable of conducting electrical supply and construction business of from 50 to 100,000 per year. Preferably one who has had experience in this line and has marked selling ability and executive ability. Application by letter. Salary not stated. Location, New York State. V-1597.

OPERATING ENGINEER with at least a B grade New Jersey license. To be thoroughly familiar with maintenance and operation of 400 h. p. Corliss engine and of horizontal return tube boilers. Position permanent. Application in person. Salary not stated. Location, New Jersey. V-1600.

SALES ENGINEER experienced with electric clock and low tension systems. Acquaintance with consulting engineers and architects in New York essential. Application by letter. Salary not stated. Location, New York City. V-1603.

ENGINEERS (8 or 9) with illuminating experience. Sales experience desirable. Will be located in district offices, and will be called District Illuminating Sales Engineers. Application by letter. Headquarters, Indiana. V-1609.

RECENT OR UNDERGRADUATES taking Electrical Engineering Courses for radio work for Summer. Application in person. Location, New York City. V-1613.

ELEVATOR ENGINEER an opening for man who can estimate on and execute general mechanical and electrical repairs, alterations and improvements to electric elevators. Executive ability an advantage. Application by letter only giving qualifications, experience, salary, etc. Salary not stated. Location, New York City. V-1622.

ELECTRICAL ENGINEERING GRADUATE. This year's graduates to enter Eng'g Dept. through drafting room. Apply by letter giving experience in detail, sample of lettering and photo. Salary not stated. Location, Western Pennsylvania. V-1634.

REPRESENTATIVES for a radio school. Evening work. This will not interfere with a man's position which he may hold in the daytime. 3 men residing in Brooklyn and 4 men residing in N. Y. C. V-1640.

SALES MANAGER. Large manufacturer located in East-Central section desires man familiar with sale of raw materials and primary products. Prefer man acquainted with steel and allied industries. Write fully stating experience and salary desired. Application by letter. Headquarters, Ohio. V-1653.

COLLEGE GRADUATES (one or two) with two to four years experience for drafting work. Age 26-28 years. Some experience in field on heavy construction and part in drafting-room in a central office. Work would consist of designing and detailing concrete and steel structures in connection with hydroelectric developments and estimating and checking same. Ability to make hurried preliminary estimates covering entire hydroelectric plant layout highly desirable. Application by letter. Salary not stated. Location, Mass. V-1655.

ENGINEERS to sell X-ray service to doctors and dentists. Bring letter of recommendation. Application in person. Headquarters, N. Y. C. V-1663.

ELECTRICAL ENGINEER who understands railway control, preferably one who has had 5-10 years maintenance experience. Application by letter. Salary not stated. Location, Pa. V-1669.

MASTER MECHANIC for beet sugar refinery technical graduates throughly familiar with operation of boiler house, evaporation equipment conveying machinery and machine shops. Must be at least 30 years old. Position for immediate acceptance. Application by letter. Location, Ohio. V-1670.

RECENT GRADUATE E. E. with 1-2 years experience. Some controller design experience. Part time drafting and development work. 1922 graduate will be considered. Application by letter stating age, education, etc. Salary not stated. Location, N. J. V-1671.

SALES ENGINEER. Young single man having practical experience with detail electrical switchboard apparatus, such as Circuit Breakers and Instruments. Sales experience not necessary. State age, experience and salary expected. Location, Philadelphia territory. V-1683.

INSTRUCTOR in electrical engineering duties commencing September 15th. Must be a university graduate, preferably with one or two years practical experience in electrical work. Opportunity to pursue post-graduate studies. Application by letter giving qualifications and references. Location, New York State. V-1688.

SALES ENGINEER acquainted with Public Utilities and Manufacturing plants in Jersey. Knowledge of chemistry is desirable. Application by letter. Salary not stated. Location, New Jersey. V-1703.

ELECTRIC MAINTENANCE ENGINEER 30-40, to take entire charge of electrical side of large manufacturing plant. Application in person and by letter. Location, New York State. V-1708.

TECHNICAL INVESTIGATORS (3), 2 years practical experience for time study, estimating and rate setting. Some mechanical ability, electrical experience valuable. Tactful, good personality and able to get along well on job. Application by letter. Location, New York City. V-1709.

DESIGNER, with experience on carbon circuit breakers and other control devices. Technical man preferred. Application by letter stating age experience and salary expected. Salary not stated. Location, Pa. V-1713.

YOUNG ENGINEER who has a little chemistry knowledge in connection with manufacture of Incandescent Lamps. Application in person. Salary not stated. Location, N. Y. V-1718.

MECHANICAL ENGINEER with some sales experience to sell high pressure valves. Application by letter. Salary not stated. Location not stated. V-1719.

ELECTRICAL ENGINEER familiar with utility accounting who can qualify as a cost and efficiency analyst, in connection with gas and electric operation and construction. Position offers opportunities for advancement with a rapidly growing company and salary would depend upon ability. Application by letter. Location, New York State. V-1724.

SALES ENGINEER with electric R. R., car lighting equipment and signal experience. This experience is absolutely essential. Application by letter. New York City. V-1735.

ELECTRICAL ENGINEER experienced on 100,000 volt high tension transmission lines to do computing under supervision. Temporary. Application by letter. Location, New York City. V-1739.

FIELD ENGINEER, C. E. preferred. Surveying, setting grades for installation of pipes in New York City. Application in person. V-1744.

GRADUATE ELECTRICAL ENGRS. (7) with 2-5 years experience in general designing and work about Public Utilities organization. Application by letter. Location, Pa. V-1746.

GRADUATE ELECTRICAL ENGRS. (7) with 5 years experience in substation and switchboard design in Public Utilities organization. Location, Pa. V-1747.

ENGINEER practical and technical graduate to be able to handle Power House operation, and at same time be qualified to know what efficiency should be produced and be able to secure this. Plant consists of approximately 6000 h. p. direct oil-fired boilers, and 3500 h. p. of waste heat boilers attached to reverberatory furnaces. About one half steam is used by reciprocating engines, converter blower and blast-furnace blower engines, with one Root Mixed Pressure Turbine Blower being installed. Other half of steam is consumed by steam turbines generating electric power. Application by letter. Salary not stated. Location, Mexico. V-1754.

PHYSICS INSTRUCTOR to start work Sept. 1st. Only two classes of men considered those who have had teaching experience and expect to continue in profession, and those who have had good engineering training and engineering experience, but who plan definitely to go into teaching to stay. Takes at least two years to break even a good man in on work, and it is impossible that we should knowingly employ a man who does not take teaching seriously. Application by letter. Salary according to qualifications. Location, North East. V-1755.

TECHNICAL GRADUATE with considerable designing experience. Major work is of a mechanical nature on stationary structures involving practically no moving parts. Electrical knowledge and knowledge of transformer construction advantageous, but after all, it is fundamental mechanical knowledge that is most essential. Experience in tank construction and in structures involving rolled plates and shapes also desirable. A great deal of electric and autogenous welding is done on work involved, and here again, experience will assist him. Experience in standardizing essential. Main functions will be to gradually polish up desirable standards and assist in selling the idea of sticking to these standards. Application by letter. Salary not stated. Location, Pa. V-1761.

ELECTRICAL MANUFACTURING PLANT offers apprenticeship course for boys 13-17 who possess mathematical ability. Will be given courses in calculus, mechanical and electrical theory, chemical shop work, etc. Half time will be spent in commercial work which will be paid for. Application by letter. Salary not stated. Location, Mass. V-1774.

DESIGNER of air compressors on details. Application in person or by letter. Location, New York City. V-1776.

YOUNG MECHANICAL ENGINEERS (3) with some selling experience to handle heating, ventilating and plumbing supplies. Application by letter only. Location, New York City. V-1778.

SALESMAN to handle piston rings. Application in person. Drawing account and commission. Location, Metropolitan District. V-1780.

PRACTICAL WORKING MASTER MECHANIC, aggressive personality to supervise candy factory. Knowledge of German desirable but not essential. Application by letter. Location, New York City. V-1782.

ENGINEER to design and supervise distribution system similar to New York or Boston. Alternate current distribution experience essential. Must be able to supervise underground work and while an office position must be familiar with both outside and inside work. Application by letter. Salary not stated. Location, New York. V-1787.

ENGINEER with acquaintance among architects, engineers and manufacturers in New York trade territory, and possessing selling ability which can be proved by past experience, for company manufacturing industrial window shades for all types of windows. Should be moderate young man with an abundance of energy and ambition. Application by letter. V-1789.

ENGINEER between the ages of 30-45, who has had at least 6 years of actual experience in combustion work in burning lower grades of fuel under hand fired and stoker feed boilers. Technical training must consist of mechanical-electrical engineering. Must have had at least 5 years experience on operation of Prime Movers, especially turbines, and electrical knowledge of conditions existing in a modern power plant.

Must be willing worker and personally capable of doing any work that is under his charge. Application by letter. Location, Illinois. V-1790.

SALESMAN to handle Electric Tools and Woodworking Machinery. Application in person. Salary and commission. Headquarters, New York City. V-1795.

ELECTRICAL or MECHANICAL ENGINEER who has had sales organization experience, to be given charge organizing sales of farm electric light and power plants. Application by letter. Salary not stated. Location, Central West. V-1796.

ASSISTANT SUPERINTENDENT of Power for textile mill for supervision of modern 4500 kw. plant equipped with Edgemoor boilers, G. E. turbines and Wheeler feed water apparatus. Also to supervise 2200 volt overhead distribution, induction motors, mill and residence lighting and automatic telephone system. Must be in good health to stand tropical climate. A single man is desired under 30 years of age. Furnished quarters and good salary. Application by letter. Location, India. V-1803.

1922 GRADUATE ELECTRICAL ENGINEER with good personality. Application in person. Salary not stated. Location not stated. PAID AGENCY. V-1807.

SUPERINTENDENT of condenser and radio factory. Must have good shop experience. Application by letter. Salary not stated. Location, New York City. V-1818.

ELECTRICAL DRAFTSMAN, exp. in Power House Substation and Switchboard Design and layout. Application by letter stating education, experience and salary expected. Send photograph if possible. Location, Ill. V-1829.

TRANSFORMER DESIGNING ENGINEER with well known British firm of electrical engineers. Must have had first class experience in design and manufacturing of Large High Tension Transformers. Application by letter giving full particulars of experience. Salary not stated. Location, England. V-1830.

ESTIMATOR with successful estimating experience upon general heavy electrical construction work for head of estimating dept. by old established electrical contracting company in the east. Application by letter. Salary not stated. Location, N. J. V-1831.

HYDRAULIC DESIGNER for hydroelectric stations for plant layout. Application by letter. Salary $175-$200. Location, N. Y. C. V-1832.

DRAFTSMAN & ESTIMATOR. Young college graduate preferred for boiler smoke stack and tank work. Application in person. Salary not stated. Location, N. Y. V-1833.

DRAFTSMEN (12 or 15) to place in Steam Turbine Department, preferably those who have had a Technical education and at least 5 years experience on steam work. Application by letter. Salary not stated. Location, Mass. V-1838.

RADIO & ELECTRICAL ENGINEER wanted to take charge of Sales and development work of radio and electrical wiring device specialties. Splendid opportunity for ambitious young man to make his own future. State experience, references and salary required to start. V-1900.

MEN AVAILABLE

ELECTRICAL ENGINEER, technical graduate; Assoc. A. I. E. E. Age 28. Six years experience in testing laboratory radio, chief engineer of marine installation and maintenance; remote control, machine tool application, estimating and construction work. Desires permanent position with well established company, planning, estimating and following up progress of jobs. Location preferred Newark or New York City; available one month. E-3443.

GENERAL MANAGER. Over twenty years experience in Construction, Operation, management Public Utilities. General Manager large Railway, Gas and Power Company prior to the war. Know the business from the coal pile to the public. Successful executive, energetic and tactful. Age 47, married, American, several years experience abroad, speak Spanish. Available now. E-3444.

SALES MANAGER, graduate Electrical and Mechanical Engineer University California, fourteen years experience desires connection sales executive property or company requiring commercial expansion and rejuvenation and where permanent future and advancement will depend upon new revenues produced. At present employed. Communications with high types of organizations solicited. E-3445.

ELECTRICAL ENGINEER, fifteen years experience, last five in design of Central and Substations, desires position as Chief Engineer with company doing work of this character. Could take responsible charge of design of Electrical equipment and transmission system. At present employed, but desires more responsible position. E-3446.

ELECTRICAL ENGINEERING FACULTY MEMBER desires to make connection with organization in Chicago or vicinity. Has had experience in central station, experimental, commercial and consulting work. Time available, 15 hours per week. At present employed by an organization which is handicapped by inability to adequately finance. A change is therefore desired. E-3447.

SALES ENGINEER and EXECUTIVE with 15 years manufacturing, sales and merchandising experience desires responsible position preferably in or near Pittsburgh. Would consider Sales Agency for reputable manufacturer. Age 35, married, at present vice president of highly successful corporation marketing nationally known line electrical household applicances. E-3448.

GRADUATE ELECTRICAL ENGINEER with initiative and ability, age 34, 8 years broad practical experience; 6 years central station power lighting and distribution; 1 year consulting engineering work; Assoc. A. I. E. E. and W. S. E. desires real opportunity with public utility or consulting engineer. Best of references. E. 3449.

SUPERINTENDENT distribution or manager small plant. Fourteen years present position superintending distribution to 20,000 customers. Reputed for square dealing and commendable service; very successful dealing with help, municipal officials and public. Twenty-four years general experience; accustomed to being available at all hours. Salary not primary object. E-3450.

CONSTRUCTION ENGINEER—age 37, seventeen years practical experience, Technical graduate, at present resident in Ontario, Canada. Desires position as construction or maintenance superintendent. Assoc. A. I. E. E. E-3451.

TELEPHONE ENGINEER—16 years experience, capable of preparing plant extensions and estimates, cost studies, commercial surveys, and fundamental plans, loop and trunk studies. Has working knowledge of traffic, manual and machine equipment and transmission problems. E-3452.

ELECTRICAL CONSTRUCTION SUPERINTENDENT, 7 years experience in Spanish speaking America, 10 years in U. S. Best references. Prefer position outside of U. S., but not important. 37 years of age and married. Will be free Oct. 15th. E-3453.

TECHNICALLY EDUCATED MAN—age 26, desires position with utility company, leading to managerial work. Two years practical experience, consisting of handling men, testing of single and polyphase watthour meters, power house and transformer maintenance, banking and accounting. Three years college—Electrical Engineering—student member A. I. E. E. E-3454.

AUTOMATIC SUBSTATION ENGINEER, 18 months G. E. tests 2½ years experience in the design and layout of all kinds of switchboards, switching apparatus and automatic station equipments; familiar with the details of latest automatic station practise; desires position in connection with installation and operation of automatic station equipments and other switchboard apparatus. Technical graduate. E-3455.

GRADUATE ELECTRICAL ENGINEER, would like to become connected with a Public Utility. Two year test course with the Westinghouse Elec. Co. Two years as Elec. Eng. for an Industrial firm. Three years with Power Co. on construction, operation and maintenance work. Salary expected $2400. E-3456.

RECENT ELECTRICAL ENGINEERING GRADUATE, University of Michigan. Age 27. Three years' practical drafting and general engineering experience with steam railroad. At present in engineering department of steam railroad. Position wanted with electric railroad or some other well established electrical concern. E-3457.

MINING ENGINEER, technical graduate, 20 years experience construction, exploration, milling, management and examination, open for engagement. Fluent Spanish. New York interview. E-3458.

TEACHER—Member A. I. E. E. Experience two years Westinghouse Student Course, three years electrical sales, nine years selecting and training technical graduates and four years Professor of Electrical Engineering. Desires employment either in industrial educational work or teaching electrical engineering. Can report in September. E-3459.

ELECTRIC RAILWAY ENGINEER—Experienced in all phases of Light and Heavy Traction of both A. C. and D. C. Types. Will consider connection of either Sales or Railway nature. E-3460.

MECHANICAL and POWER ENGINEER, technical graduate, B. S., M. E. eight years broad experience, machine shop, metallurgy, sugar engineering, industrial and power plant practise, operation, design, layout, calculations, heat balance, utilization and distribution of steam, water, coal, power, etc., investigation, research, reports. Executive and business ability. E-3461.

GRADUATE E. E. and PATENT ATTORNEY wishes position as operating executive where an abundance of honest effort, coupled with his particular experience and training, will lead to advancement. Must be permanent. Age 26, six years experience. Can plan and carry out your development work economically and practically from both engineering and patent viewpoints. Available 30 days. E-3462.

ELECTRICAL ENGINEER—Technical graduate, age 26, married, desires position as engineer with public utility corporation. One year graduate student course at Westinghouse. Three and one half years on design and construction of distribution and power apparatus. Now employed E-3463.

ENGINEER—Inspector and tester of electrical and mechanical power machinery, meters and storage batteries for marine installations (6½ yrs.) previous experience including industrial and railway power plants, high tension feeder substation devices, track bond test car, etc., (8½ yrs.) will apply above to like problems. Salary $2600. E-3464.

YOUNG ENGINEER, graduate, married, three years experience; design and construction, power plants, substations, power installations, electrical generation and distribution, commercial work; with General Electric Co. and present employer. Desires connection with Company offering opportunity to becoming permanent member of organization. Would welcome further experience in above class of work. E-3465.

TECHNICAL GRADUATE—Assoc. A.I.E.E., age 33. Completed Westinghouse Graduate Students' Apprentice Course, East Pittsburgh, Pa. Ten years' experience in railway, light and power work, both commercial and operating. Desires position as Assistant Superintendent, or position leading to it, with Public Utility, either Railway or Power Company. Now with large power Company. E-3466.

ELECTRICAL DESIGN OR RESEARCH. Age 29, A.B., Johns Hopkins, E.E. Columbia

University, G. E. test. Six years general engineering experience. Desires design or research work with a progressive manufacturer of electrical equipment, to act independently or as an assistant. Highest references. E-3467.

TECHNICAL GRADUATE nineteen eleven, two years selling, seven years assistant manager small electrical concern, desires position in sales department manufacturer. Because of confidence in quickly attaining responsible position, is willing to start at bottom with right company. E-3468.

ELECTRICAL ENGINEER, graduate of 1916, familiar with electrical equipment for power plants and substations, especially those for industrial plants. Broad experience in layout of such stations. Familiar with hand and automatic switching equipment. E-3469.

ELECTRICAL ENGINEER, experienced in central station work, desires a position covering any or all of the following branches, depending on the size of system: power stations, substations, overhead distribution and underground distribution. Character of position and salary at the start secondary if bright future is offered. E-3470.

ELECTRICAL ENGINEER. Several years large railway design, construction, operation of power stations, distribution, lines; engineering cars, equipment, transportation problems, shops buildings. Valuations, rates of lighting and railway companies. Design, construction transmission lines. Statistics, economic studies. Industrial engineering, financial investigations, layouts, studies processes, organization and management. Available now. Qualified responsible executive or engineering position with utility of industrial concern. E-3471.

EXECUTIVE ENGINEER, electrical graduate, 15 years' experience with large power and construction companies in office and field supervision, design, construction, operation and maintenance of power plants, substations, electric railways, transmission lines and distributing systems; knowledge of spanish, age 39, married, at present employed. E-3472.

PROFESSORSHIP in electrical engineering desired by Member A. I. E. E. Age 45, married, E.E. degree. Ten years commercial experience, two years practical engineering experience, and nine years university teaching experience in electrical engineering. Salary desired $3500; minimum considered, $3000. E-3473.

ELECTRICAL LABORATORY ENGINEER, 12 years experience electrical and magnetic measurement, and research, desires responsible position. Growing concern, with opportunity for initiative in apparatus design and development, preferred. Was with G. E. Standardizing Laboratory (Lynn) 3 years; have since (for 9 years) been in charge laboratory work for three different concerns. Technical education; age 35; minimum salary $2600. E-3474.

ENGINEERING SUPERINTENDENT, technically educated, member A. I. E. E.; married, 20 years' experience on design and construction of power and industrial plants as Engineer and Superintendent dealing with labor, materials, costs, sub-contractors, plant equipment, also production charts and schedules, desires to locate preferably in Boston district with an industrial concern on production work, or with a construction concern or small contractor as Engineer, Superintendent or Assistant to Executive. E-3475.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before August 31, 1922.

Bergendahl, Rudolph, Chicago, Ill.
Bisek, Peter P., Williston, N. Dak.
Bowles, Edward L., Cambridge, Mass.
Bull, Hempstead S., Allentown, Pa.
Callaway, C. R., (Member), New York, N. Y.
Canivet, Jean (Member), Schenectady, N. Y.
Caplain, Philip, Brooklyn, N. Y.
Cecchini, Joseph P., Monarch, Wyoming
Craft, Warren M., (Member), New York, N. Y.
Danziger, Harold I., New York, N. Y.
Diamond, Harry, Quincy, Mass.
Dickinson, James G., Milwaukee, Wis.
Fergusson, Kenneth W. C., (Member), Winnipeg, Man.
Gannett, Robert, New York, N. Y.
Gardner, Anson B., (Member), New York, N. Y.
Gruppe, Edwin A., Rochester, N. Y.
Hammel, Fowler, Brooklyn, N. Y.
Harada, Kyosuke, Ithaca, N. Y.
Harris, Gordon, (Member), New York, N. Y.
Harris, Leonard F., Brooklyn, N. Y.
Johnson, Willard, Albany, Oregon
Jones, Horace R. J., Los Angeles, Cal.
Katayama, Kazuo, New York, N. Y.
Kirby, Robert W., (Member), Mullens, W. Va.
Lawrence, Thomas H., Lead, S. Dakota
MacMillan, Lawrence C., Chicago, Ill.
Marsh, Walter H., New York, N. Y.
Massey, Ben R., Turtle Creek, Pa.
McGorman, Samuel E., Walkerville, Ont.
McNee, Eldon R., Cicero, Ill.
Miller, James H., New York, N. Y.
O'Brien, Lawrence J., Fairfield, Ohio
Oneto, Washington, Philadelphia, Pa.
Paterson, Albert B., (Member), New Orleans, La.
Pickard, Edward E., Philadelphia, Pa.
Price, Don, Norwich, N. Y.
Racaj, Jose A., Wilder, Vt.
Ramsey, Marion A., E. Pittsburgh, Pa.
Risk, George, Jr., New York, N. Y.
Rivers, Fabian N., New York, N. Y.
Roach, Fred J., New York, N. Y.
Rocca, William S., West New York, N. J.
Rodey, Bernard S., Jr., New York, N. Y.
Rodriguez, Juan M., Mexico, D. F., Mex.
Sawyer, Charles N., Camp Alfred Vail, N. J.
Scheel, Alfred A., Corning, Iowa
Scott, Lester F., Sacramento, Calif.
Smith, Kyle, New York, N. Y.
Smith, Myron H., New York, N. Y.
Steinhoff, Horace W., Brooklyn, N. Y.
Taylor, William H., N. Troy, N. Y.
Thayer, Alfred H., Upland, Calif.
Tsutsumi, Isamu, New York, N. Y.
Tufts, Bowen, Boston, Mass.
Turnbull, W. Gordon, Toronto, Ont.
Warner, Munroe F., (Member), Langeloth, Pa.
Winter, Marvin N., Far Rockaway, N. Y.
Total 57.

Foreign

Ahmed, Abdel Z., Witton, Birmingham, Eng.
Celis, Atlio, (Member), San Juan, P. R.
Damania, Sorab B., Karjat, India
Franklin, Harry F., Guatemala City, Guat.
Lane, William J., Christchurch, N. Z.
Leonard, William J., Guatemala City, Guat.
Matsusu, Isawo, (Member), Tokio, Japan
Padbidri, Narsingrao S., Ft. Bombay, India
Spencer, Charles G., (Member), Stockholm, Sweden
Swales, W. J., Ancon, C. Z.
Walton, John, Manchester, Eng.
Total 11.

OFFICERS OF A. I. E. E. 1922-1923

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GEORGE A. HAMILTON

Secretary
F. L. HUTCHINSON

A. I. E. E. COMMITTEES

The list of committees is omitted from this issue, as new appointments will be made for the administrative year commencing August 1. The new committees will be listed in the September issue.

A. I. E. E. REPRESENTATION

A complete list of A. I. E. E. representatives on various bodies will be published in the September issue.

A. I. E. E. SECTIONS AND BRANCHES

A complete list of the Sections and Branches of the Institute, with the names of the chairmen and secretaries, will be published in the September issue of the JOURNAL.

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGS AND OTHER TRADE PUBLICATIONS

Mailed to interested readers by issuing companies.

Welding Wire.—Booklet. Wire for Electric and Gas Welding. John A. Roebling's Sons Co., Trenton, N. J.

Chain Drive.—Catalog 125. Describes "Link-Belt" silent power transmission drives, and illustrates their use in various industries. Link-Belt Co., Chicago.

Circuit Breakers.—Bulletin 560, 4 pp. Describes a new line of completely enclosed circuit breakers for all industrial applications. Roller-Smith Co., 233 Broadway, New York.

Steam Turbines.—Catalog, 16 pp. Describes "DeLaval" velocity stage steam turbines for use in driving high speed pumps, small generators, etc. The De Laval Steam Turbine Co., Trenton, N. J.

Moulded Insulation.—Catalog, 16 pp. Describes various classes of insulating material applicable in the electrical industry, manufactured by the Garfield Manufacturing Co., Garfield, N. J.

Condenser Tubes.—Catalog. Describes "John Crane" metallic packing for condenser tubes and explains the bonding of tubes to tube sheet to prevent electrolytic action. Crane Packing Co., 1804 Cuyler Ave., Chicago.

Circuit Breakers.—Book, 100 pp., "Protection Up-to-Date." Describes "U-Re-Lite" circuit breakers for central stations, industrial applications and other uses and illustrates typical installations. The Cutter Co., Philadelphia.

Synchronous Motors.—Bulletin 1124, 20 pp. Illustrates various industrial applications of synchronous motors for belted, coupled or direct connected service, driving air compressors, motor generator sets, in rubber, flour and paper mills, ice plants, mines, etc. Allis-Chalmers Manufacturing Co., Milwaukee.

Steam Turbines and Alternators.—Bulletin 1122, 54 pp. Describes the steam turbine and generator units of the condensing and non-condensing type with pressure operated by pass valve, for sugar mills, refineries, saw mills, power and manufacturing plants. Allis-Chalmers Manufacturing Co., Milwaukee.

Lighting.—Booklet, 22 pp., "Scientific Street Lighting." Discusses the trend of modern ornamental street lighting practice especially concerning high intensity, greater mounting heights, light distribution considerations, spacing of units and economy of installation and operation. The Holophane Glass Co., 342 adison Ave., New York.

Oil Burning Systems.—Catalog, 80 pp. Describes the installation, operation and maintenance of mechanical oil burning systems and fuel oil burners in which the oil is atomized by low or high pressure air and steam. The catalog is illustrated in color and contains about 25 tables of data compiled from authoritative sources. Schutte & Koerting Co., Philadelphia.

Heating Elements.—Bulletin, 12 pp. "Electrical Heating Reference Data." Describes the method for determining material adapted to certain specific conditions and the proper size and length of resistance wire to be used, as well as suggestions for the design of the heating element. Charts are included illustrating current-carrying capacities of resistance ribbon and strip. The Electrical Alloy Co., Morristown, N. J.

CHANGES IN THE INDUSTRY: NEW APPARATUS

The Okonite Company, Passaic, N. J.—A branch office has been opened at San Francisco, in the New Call Building, S. Herbert Lanyon, Manager.

The Louis Allis Co., Milwaukee.—This firm has changed its name, previously *The Mechanical Appliance Company*, manufacturers of the "Watson" motor. No change, however, in ownership or personnel has been made.

Morganite Brush Co., Inc., New York.—Announcement is made of a change in New England representatives. J. F. Drummey, 75 Pleasant St., Revere, Mass., has been appointed, succeeding the R. W. Lillie Corporation.

Atwater Kent Manufacturing Company, Philadelphia. A line of radio apparatus is now being produced by this company, including variometers, variocouplers, audio-frequency amplifying transformers and a rheostat for the vacuum-tube filament control.

Signal Engineering & Manufacturing Company, New York.—This concern has taken over the manufacture and sale of several products formerly manufactured by the Klaxon Co., Newark, N. J., including power relays, telephone extension relays, solenoid bells and a-c. duplex horns.

Rome Wire Company, Rome, N. Y.—This company has purchased the inventory and equipment of the Toledo Enameled Wire Products Co., Toledo, O., which will be installed in the Rome Wire plant at Rome, N. Y. The Toledo Company manufactured mainly large and intermediate sizes of enameled and cotton-covered wire.

Killark Electric Manufacturing Company, St. Louis. Two new sales agents have recently been appointed by this company.—Irving M. Popkin, Bowles Building, Detroit, Michigan, will handle the Killark products in Michigan, and the Nicholson Sales Company, Keller Building, Louisville, Ky., will cover the Kentucky and Tennessee territory.

Bus Bar and Conductor Fittings.—Bulletin No. 38, 48pp. Describes a complete line of fittings for bus bars and conductors, including clamps, clamp lugs, connectors splicing sleeves, terminal lugs, all of which are illustrated in a large range of sizes and dimensions. The bulletin also contains some useful data on copper tubing, bars and rods, heating effects of current carrying capacities of wire and other information. Delta-Star Electric Co., 2433 Fulton St., Chicago.

National Carbon Company, Inc., Long Island City, N. Y.—Two finishing plants, one at 237 E. 41st Street, New York and the other at 560 W. Congress Street, Chicago, have been established to supplement the emergency department maintained for some time at the Cleveland factory. Both plants will carry a complete stock of Columbia carbon, graphite and metal graphite brushes, and are prepared to furnish all sizes equipped with Standard types of shunt connections, or other special methods of finishing.

Johns-Pratt Company, Hartford.—This firm's selling arrangement through the Johns-Manville Company was recently dissolved and they have established a Pacific Coast branch of their own. This office is located in the Call Building, San Francisco, Cal., and will be in charge of A. J. Moan. Mr. Moan was with the Johns-Manville Company for a number of years and therefore is entirely familiar with the Johns-Pratt line of Noark fuses and meter protective devices, moulded products, etc.

The company has also opened a New York office, which is located in the Liggett Building, Madison Avenue and 42nd Street and a Boston office, at 161 Summer Street.